S. HRG. 103–185

SUPERCONDUCTING SUPER COLLIDER

JOINT HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

AND THE

SUBCOMMITEE ON ENERGY AND WATER DEVELOPMENT

OF THE

COMMITTEE ON APPROPRIATIONS UNITED STATES SENATE

ONE HUNDRED THIRD CONGRESS

FIRST SESSION

ON THE

DEPARTMENT OF ENERGY'S SUPERCONDUCTING SUPER COLLIDER PROJECT

AUGUST 4, 1993

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SUPERCONDUCTING SUPER COLLIDER

WEDNESDAY, AUGUST 4, 1993

U.S. SENATE, COMMITTEE ON ENERGY AND NATURAL RESOURCES, AND THE SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT OF THE COMMITTEE ON APPROPRIATIONS,

Washington, DC.

The committees met, pursuant to notice, at 9:37 a.m. in room SD–366, Dirksen Senate Office Building, Hon. J. Bennett Johnston, chairman of the committee on Energy and Natural Resources, presiding.

OPENING STATEMENT OF HON. J. BENNETT JOHNSTON, U.S. SENATOR FROM LOUISIANA

The CHAIRMAN. The hearing will come to order.

Today we consider the Superconducting Super Collider. In this morning's hearing we will consider the science of the super collider. We will have a distinguished panel including Dr. Jack Gibbons, who is the Director of the Office of Science and Technology Policy of the White House, who will speak about the administration's position on the project.

On our second panel we will have Professor Steven Weinberg, who is a distinguished Nobel laureate, high energy physicist, and who I think the Senators here will find to be a very interesting witness.

Then we will have as part of the second panel Professor Philip P. Anderson from Princeton who is also a Nobel laureate and a very distinguished scientist, who will give the other side of the Superconducting Super Collider, and we will have Mr. Robert Galvin, who is chairman of the Executive Committee of Motorola, who will talk about the super collider and its applications and the importance of this kind of science to industry, to America, and to our future.

This democracy expresses itself through a constitutional system and Congress, and the Congress faces a very serious question with the SSC. It is not the first time that the Congress has faced this question—2 years ago the first motion to strike the Superconducting Super Collider came before the U.S. Senate. We had a full-scale debate at that time.

All of the questions that now are to be considered were then at issue before the U.S. Senate. The question of priorities, the question of the importance of the science, the question of whether this kind of basic science is important to mankind, important to the

United States, all of those issues were there, presented, and fully and completely debated.

The U.S. Senate, after using our privilege of extended debate, the only legislative body, I guess, in the world that has that privilege of extended debate—after extended debate, the Senate voted, and voted by a rather comfortable margin that yes, we should continue the Superconducting Super Collider.

Last year, again the question was presented. The same questions, the same issues—the importance of the priority of this science, its importance to mankind, its importance to us as human beings—the same questions of budgetary stringency, because the budget numbers then were well-known, the issues were well-known, and again by a vote of a very comfortable margin—if I recall, 62 to 37—the Senate said yes, we want to continue, and indeed, last year we put another $517 million into the collider.

Today, we are $1 billion further along with the Superconducting Super Collider. Some of the unknowns about cost and about the science that were raised 2 years ago are now known. Two years ago we had not had the string test on the magnet. We did not know whether the design of those magnets was going to be proper, whether they were going to work properly or not. Now that has been done, and that is to a large extent the long pole in the tent as far as the Superconducting Super Collider is concerned. We did not know some of the questions about drilling in the Austin chalk. Now we are 12 miles along through that chalk.

Many of those questions about the technology, about the science, have been answered, yet today—and indeed last night we all heard the President talk about budget priorities. That is really the only thing that has changed about the super collider, sort of the emotional mood of the Congress and of the country.

For that reason, not because of any failure of the science, not because of any mismanagement of the project—although to be sure we will hear this afternoon about claims about mismanagement and the need to improve that management, and in much of that criticism I concur, and I think you will hear the steps to be taken this afternoon to cure those problems of management, particularly of auditing.

But make no mistake about it, with a project of this kind, one that involves emerging and evolving science and technology, you cannot draw up a set of plans and give them to the architect and the engineer and say, go build it. You have to change and modify and merge and massage as it goes along as you invent the science and the changes in the science as it goes, and only the scientists really know the questions of the science.

So there is a natural tension between distinguished scientists on the one hand and skilled builders and managers on the other hand. We have had it in every project we have done of this size, whether it be Fermi Lab, whether it be the Manhattan Project, whether it be dozens of major projects around this country successfully involving scientists on the one hand and builders and managers on the other hand.

We can—and I hope we can smooth out as much of that natural tension as possible, but do not ever think that you can build one of these kinds of projects like you can build a tract house. It simply

cannot be done. There is always going to be some uncertainty, there is always going to be some change, there is always going to be continuing challenges.

The good news about this project is that the biggest challenges have been solved. The magnets were redesigned early on, and indeed, it was that redesign of the magnets some 3 or 4 years ago that caused the first increase in cost, and that increase in cost was absorbed and successfully done, and since 1990 those costs have been well under control.

A fundamental question is whether a country which has some budget problems can afford basic science, indeed, whether we ought to be involved in anything other than applied science, and indeed, the further question arises whether you should even do applied science. Some would say, let the market decide, and let private enterprise pay for all science. If it is worth doing, the private industry can do it, otherwise it is industrial policy.

I feel with every bit of my being that this country, if it is to stay great, must stay on the cutting edge of science. We are the leader in the world, not only in high energy physics but in a whole range of scientific endeavors. We have that leadership now.

But what does it tell the world if $2 billion into this project, 20 percent complete, 12 miles of tunnel built, 7,000 employees hired, people displaced from their property, the State of Texas having passed a half billion dollars worth of bonds, money spent—if at that time, after two votes of the U.S. Senate and $1 billion spent, after those two votes we suddenly say, we have changed our minds, what does that say for our leadership? What does it say to those scientists? What does it say about the United States?

I think it would be a horrendous message for this country. It would tell us that we could never start another big science project. How could we? How could we?

So I say, at a time of budget stringency, at a time of difficulty, now more than ever, we need science. This is a competitive world, a technological world where we are going to compete not by the quality of the sweat of our brow, but by the quality of our technology. If we are going to stay on top, it has got to be through technology.

I have been to China this year—1.2 billion people, able, energetic, organized. There are other emerging countries. We have a new trade agreement with Mexico. We cannot compete with them on wages per hour or even productivity when it comes to sweat and manpower. We can compete only through the excellence of our technology, and that is the issue facing the Congress squarely in the face today.

It is an issue as broad as the SSC, but a lot broader than that. In a sense, it is the whole future of science, this question of whether this 43/1000ths of 1 percent of the Federal budget should be spent in order to keep the preeminent position of science in the world.

[A prepared statement of Senator Wallop follows:]

PREPARED STATEMENT OF HON. MALCOLM WALLOP, U.S. SENATOR FROM WYOMING

The subject of today's hearing, the Superconducting Super Collider, has been scrutinized on many fronts since the inception of the project. There have been allegations of mismanagement and potentially large cost overruns as well as

continuing challenges from within the scientific community to the desirability of the project. These have all been cited by opponents of the SSC as reasons to cancel the project. But poor management and cost overruns are common afflictions of any large construction project, particularly within the federal government. That is not to say that such problems are incapable of resolution. Nor is lack of universal enthusiasm among scientists unique to the SSC project. Disagreement is always most abundant on the frontiers of science. It seems premature to consider canceling a project we have determined to be worthwhile and in which we have already invested nearly $2 billion unless we find that its present problems cannot be solved.

The real issue we are grappling with is at what funding level, in times of tight budgets, we should continue our commitment to a multi-billion dollar pure science project that is already 20% complete but whose final cost estimate is a moving target. Extending the completion date three years as proposed by the Administration will raise the final price tag to at least $10 billion. That total does not take into account any anticipated cost overruns attributable to other factors. Obviously, DOE must come up with a credible final cost estimate. Without it, it is difficult at best to make any judgments about timing and appropriate funding levels for the SSC. Hopefully the Department can clarify that issue for us today.

The CHAIRMAN. Senator Hollings.

STATEMENT OF HON. ERNEST F. HOLLINGS, U.S. SENATOR FROM SOUTH CAROLINA

Senator HOLLINGS. Thank you very much, Mr. Chairman. I apologize. I had gotten notice of our subcommittee meeting, and they said that Dr. Gibbons and Secretary O'Leary were appearing, and in all candor I said, well, there is my friend Chairman Johnston, he has got his energy technology initiative put onto the defense authorization bill, and now he is going to make a record before the Defense Appropriations—I mean, before the Energy Appropriations Subcommittee.

So I raced on over here to get a decision out of Dr. Gibbons, and I will—I will not belabor the committee on the super collider, but I will take advantage of having walked all the way over here to find out something from Dr. Gibbons here when my question time comes.

Let me just say to the good audience here, we have got to get on the cutting edge of paying the bill. I love science, and that is my committee—Commerce, Science, and Transportation. We have got the National Science Foundation, we have got the Space Agency, and we have got tremendous respect for the leadership and talent, but there comes a time in your political body that it has got to determine, or discern, I should rather say, between the necessary and the desirable.

There are a lot of fine desirables that this Senator would just love. I wish I were allowed loose in the candy shop to pick anything I want, like a super collider, but I cannot afford it. In fact, you cannot afford the lights that are on. You cannot afford to pay for Dr. Gibbons and Senator Hollings. In fact, you cannot afford to open up this building.

The first thing to keep the Government open this morning was to borrow $1 billion and add it to the debt. They are running all over the floor of the Congress hollering about the largest tax increase in history. That is nonsense. The largest tax increase is on automatic pilot, deficit taxes. If we do nothing, we are going to increase deficits by $310 billion, which is the largest tax increase that was given to President Clinton.

Here is a young man who had been down in Arkansas paying the bill, balancing the budget for 10 years. He comes to this crazy town, and they jump all over him like they know something about fiscal responsibility and all of the other little slogans that they have got here. It comes in the outyears, it comes in this year. Better watch out Middle America. Look out for that. That is child's talk.

What we have got is a tremendous task for all of us, and in that context I cannot support the super collider. I believe every word the witnesses would say. We have in the law a demurrer. That is when we look in the face of the pleadings, admit to everything on the face of the pleadings, and in this case admit to everything Dr. Gibbons, Mr. Galvin and all the rest of them will attest to, and still say you do not have a cause of action, because we don't got the money.

Thank you.

The CHAIRMAN. Senator Bumpers.

STATEMENT OF HON. DALE BUMPERS, U.S. SENATOR FROM ARKANSAS

Senator BUMPERS. Mr. Chairman, thank you very much.

We are gathered here once again in a frantic effort to save the collider. The chairman of the committee accuses me of being president of the Flat Earth Society because of my opposition to the collider, and of course I think that is maybe better than being a member of the Flat Broke Society, which is where we are headed.

I would say that I have no quarrel with particle physicists who want to build a collider, and I know that the information they want to get would be of an immense satisfaction if they get it, but every time the collider gets in trouble, we move from finding the origin of mass, which, incidentally, Senator Byrd insists you can find in 1 Genesis—we move from finding the origin of mass to cancer cure.

Now, if I thought for an instant there was a cancer cure in this project, I might change my thinking. I am as absolutely certain as I am of my name that curing cancer is not one of the results we are going to find from this. I do not know anything about physics, but I read—I believe it was Dr. Anderson, who would not even be present here if we had not insisted that we have at least one scientist opposed to this project, and that is what we have got—one.

Now, Mr. President, at this point this would be a good time to say that I have a host of letters and statements from some of the leading scientists, physicists in this country who strongly oppose this project that I would like to insert in the record at this point.

[The material referred to follows:]

Amherst, MA, July 28, 1992

Honorable DALE BUMPERS,
Dirksen Senate Office Building, Washington, DC.

Re: Super collider

DEAR SENATOR BUMPERS: I am writing to express my opinion regarding the continuance of the present Supercollider project. I emphasize that I am not speaking for any organization. However, since I have been involved in many aspects of physics and other sciences in my career and have given considerable thought to this issue, I have been urged to provide you at this time with some material which I have already sent to Congressman Boehlert, as well as others.

It is my position that work on the present Supercollider project, as well as the detectors which are being built in anticipation of this (yet uncertain) machine, should be brought to a halt. If this is done, it is reasonable in due course to consider a joint, international proposal involving the European, Japanese, and U.S. scientists from the outset, afresh. There is simply no present reason, either scientifically or for any other national priority to make this either an urgent or purely domestic project. I suggest that several points are relevant in support of my position; these are not entirely what Congress and the public hear, generally speaking. The appended documentation provides further background. Similar opinions are held by many.

- U.S. leadership in "science" simply does not depend on the SSC, or even on particle physics. Whether a successful accelerator to detect the Higgs particle is made here or elsewhere, or twenty years from now, it will have little effect on science in the large. (Indeed, particle physics has made no significant contribution to the understanding of Superconductivity; it is only a "user".)
- The SSC can make only insignificant contributions to technology or economic superiority, at best.
- It is claimed that the SSC has the wide support of the physics community. This is far from true. In the first place the subfield of particle physics constitutes only about 10% of the activity in physics (enclosed is a bar graph profile by subfields). The advocates are largely in that subfield. Secondly, the SSC is certainly not the highest priority in physics overall; this is clear from an official statement by the Council of the American Physical Society. January 20, 1991.
- It is remarkable, in my view, that a body of congressional members, some trained in investigative law, do not seem to have taken even simple steps to check some of the assertions which have been made, such as independent sample polling of the membership of the Physics societies, or other scientific, engineering, or technological/industrial groups. Instead the witnesses (for the most part) have been carefully selected, particularly in the Senate, to be largely among the promoters of the SSC.
- The societal and technological claims for the SSC have been grossly exaggerated or misrepresented; the public is being seriously misled. The recent statements by Professors Geballe, and Schrieffer to the House Science . . . Committee, as well as the recent letter by Geballe, and Dr. John Rowell to Science Magazine, should certainly be brought into the Senate discussions.

These and a number of other factors lead me ever more strongly as time goes on to believe that a halt should be called. I want to emphasize that I agree that the scientific objectives in particle physics are important, but in the larger scheme of physics and science the answers will be far from providing a "final theory" except in a narrow subfield. Collectively, our other endeavors certainly have higher priority, on any basis.

Finally, I suggest that there would be much value to a fresh start, with a clean slate. There would be time to understand how a proposed $4 B project has already climbed to $11 (+??, construction only). There would be time to give a fair review to the questions now being asked about the SSC management structure, and to develop a less ad hoc procedure for future large projects. There would be time to sort out for the public what the real (honest!) expectations of benefits are. And, not the least, by broadening the base of scientific expertise to the international level, to consider a new program, there would be a more critical, extensive, and less partial review of the scientific and technological design issues and uncertainties which are currently known. I am sure that the research and design experience so far, both at the SSC and CERN, will be of some use in a future program, and not really lost.

I hope that these comments will be of use to you. It is not easy for me to oppose a project deemed so important by friends of many years. However, I have come to the conclusion that physics, science, as well as the public interest, in general, will be best served by terminating the present SSC project. When the time comes, a truly international project in this one subfield, widely reviewed, and whose societal role is clearly understood and realistically represented, would be far better for all.

I will be on extended travel beginning this Friday, July 30, until September 13. Please feel free to use this letter and any of the appended material[1] as you see fit.

Sincerely yours,

JAMES A. KRUMHANSL.

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[1] Material submitted has been retained in Committee files.

INSTITUTE FOR THEORETICAL PHYSICS,
STATE UNIVERSITY OF NEW YORK AT STONY BROOK,
Stony Brook, NY, May 3, 1993.

Senator DALE BUMPERS,
Dirksen Office Building, Washington, DC.

DEAR SENATOR BUMPERS: I am writing to you because you are the leader of the forces opposing the Superconducting Supercollider in the Senate.

On Thursday, April 29, an "educational forum" on the SSC, sponsored by the Texas Laboratory Commission, was held at the State University of New York at Stony Brook. This forum was moderated by the television commentator Edwin Newman and featured Dr. Roy Schwitters the director of the SSC. This was announced to be the first of several such forums to be held around the country in the next several months.

As a theoretical physicist with 26 years of experience and some 110 publications I want to strongly express to you my intense dismay at the way the effort to fund the SSC is undermining public credibility in the objectivity of scientific research.

The forum lasted from 10 AM to 4 PM and in those 6 hours there were exactly 2 sentences devoted to the scientific goals of the SSC; namely 1) it will give us information about the origin of mass and 2) there may be unexpected discoveries. I repeatedly asked Dr. Schwitters for more scientific justification and even reminded him of the fact that there have been 30 years of theoretical research that have passed since the Higgs mass mechanism was first proposed and that by now there are many physicists who have concluded that this mechanism is not relevant to nature. Nothing could induce Dr. Schwitters to add even one extra sentence to the justification of SSC. This is the same lack of scientific justification which characterized the debate in the Congress last year. I can only conclude that the director has no further relevant scientific arguments to present to the public to support his request for funds.

I have had an NSF grant for 20 years and can assure you that no grant from NSF is funded if there are only 2 sentences of scientific justification.

However, what was even more distasteful was the exploitation of minorities, the totally misleading claims of curing cancer, and the blatant appeal to pork barrel politics made by the director and other speakers.

One of the lunch time speakers was a black undergraduate from Virginia State University. He has a job that is connected with the SSC and gave a very moving presentation of how this experience was changing his life. It was in fact an eloquent demonstration of the need for minority scholarship programs but it has nothing to do with explaining why $8.6 billion should be spent on constructing the SSC.

Dr. Brenda Buckhold Shank, chairman of the radiation department of Mount Sinai hospital, gave a 20 minute presentation on cancer research at the SSC but blatantly ignored the fact that the protons used in cancer research have energies of some 300 Mev whereas the object of the SSC is to produce protons with energies one hundred thousand times greater. The low energy protons useful for cancer research are already available at many laboratories. Protons of the much higher energy produced by the SSC will kill you if you come into contact with them. The fact that the director would allocate 20 minutes for such a presentation indicates that he is either completely ignorant about how protons are to be used in cancer research or that he is blatantly and deliberately misleading the public.

In addition, the director was quite proud of the fact that contracts have been spread out to 48 states in an attempt to win votes in favor of funding. He seemed quite oblivious to the fact that this is precisely the practice of pork barrel contracting that wastes so much of the taxpayers money.

Finally it must be pointed out that in the printed material passed out to the audience of the forum the proponents of SSC were attempting to take credit for all sorts of scientific discoveries ranging from penicillin to superconducting magnets to parallel processing computers. The fact is that the high energy physics experiments of the last 50 years have lead to none of these advances.

There are tens of thousands of reputable scientists with the highest standards of objectivity and integrity who are doing outstanding research in this country. Many of them are funded by government programs which are administered with the utmost attention to scientific and ethical standards. It is exceedingly unfair and unjust that instead of seeing the work of these many thousands of researchers the public is subjected to year after year of deceptive appeals by the supporters of the

Superconducting Super Collider. I applaud you for your work towards the elimination of this wasteful item in the federal budget.

Sincerely,

BARRY M. MCCOY,
Professor of Physics.

Los Alamos, NM, June 28, 1993.

Senator DALE BUMPERS,
Dirksen Senate Office Building, Washington, DC.

Re: Superconducting Super Colllder

DEAR SENATOR BUMPERS: Because of the Superconducting Super Collider's high cost and poor prospects for strengthening either science or technology I urge you to continue your leadership role in opposing further spending for its construction.

The cost-benefit ratio for this project is highly unfavorable. You are familiar with the costs (which include substantial annual operating costs) so I will review only the benefits.

The astonishing fact, in view of how seriously this project has been taken by Congress, is that there would be no benefits from the results of this research to any science or technology outside the very narrow speciality of particle physics itself. The reason for this gloomy assessment originates from the nature of the phenomena to be studied: they occur naturally nowhere—not on earth, not in the solar system, not in our galaxy, not in the present universe! Moreover, there are no naturally occurring phenomena in the present universe that would even be illuminated by the research of the SSC. No current problems involving existing matter, from nuclear processes to astronomical objects, would be clarified, much less solved.

The energies to be produced by the SSC, 40 teravolts, would have relevance only to the historical physical world during an infinitesimal interval of time near the origin of the universe. Knowing more about this early interval of time will merely raise questions about the preceding intervals, involving ever higher energies—and so on, to absurdity. The brute-force approach to these questions, as exemplified by the SSC, cannot be sustained.

Even though their energies are far closer to the real world than would be the SSC's the present-day high-energy particle accelerators at Fermilab, Illinois, and CERN, Switzerland, already illustrate the esoteric and effectively empty nature of the expected SSC results. For example, the most noteworthy of Fermilab's accomplishments, many would say, has been the discovery of the "upsilon", whose obscurity outside the tiny community of particle physicists is no oversight.

In summary, the SSC is an extravagant luxury whose funding cannot be justified in this time of shrinking budgets and promising alternative research opportunities.

Sincerely,

LAURENCE J. CAMPBELL, *Physicist.*

Written Testimony by Professor Rustum Roy

Senate Hearing on the Superconducting SuperCollider

August 4, 1993

THE SCIENTISTS' CASE AGAINST THE SUPERCOLLIDER

Summary

There are three overriding reasons why the SSC should not be funded now, and by the U.S. alone. *First*, it takes away resources from other sciences, relevant to jobs and industry. *Second*, it distracts the nation and its scientists from urgent national priorities. *Third*, it is not particularly urgent science and it could wait for a decade with no loss to science or the nation, for implementation by an international body.

What is the Congress Funding if it Funds the SSC? Not U.S. Science

I speak for the 98% of American scientists who in the Sigma Xi survey refused to give any priority for public funds for the SSC. We represent the real science, the public has always believed it is supporting, as distinct from the speculative, abstract science of the SSC.

The Congress has never heard from any scientist from electrical engineering, biology, theoretical chemistry or environmental science supporting the SSC. Yet the witnesses who testify for the supecollider should clearly be recognized as a tiny subset, within physics, which represents a very modest fraction of the American scientific community.

Separating the Two Kinds of Science

There are two kinds of science:

a) **Real science** done by the vast majority of scientists in university, industry and government laboratories with which humans and society are in daily contact, which can be confirmed in 1,000 labs (and used) worldwide. This includes not only the enormous benefits of modern electronics, medicine and agriculture but also the great principles and generalizations of science mostly derived through observations in the world of technology and daily experience. They include a range of topics from the laws of motion, to $E=mc^2$ to quantum mechanis.

b) **Speculative science** which *cannot* be tested by laboratory experiments, and about which speculations can go on *forever, without any conceivable impact on humans or society.* Modern astronomy and particle physics are the most obvious examples. The SSC is a typical example of a machine to do "speculative science." Is it, therefore, very much in the interests of the latter group to either pretend that their speculations are real, or to try to pass themselves off as real scientists: the Jacob and Esau gambit.

In science policy we judge the importance of a field or discovery by quantifying the impact it has

first on neighboring fields of science. By this "Weinberg Criterion," named after Alvin Weinberg, founding Director of Oak Ridge, the SSC even if successful would rank very, very low.

Nothing the speculative science the SSC *can* discover *can ever* have any impact on chemistry, biology, engineering science, materials, agriculture. Indeed it is becoming obvious that our real sciences are the truly basic sciences because such science impacts particle physics very directly .

Fooling the Public

For the last forty years, partly unconsciously and recently more purposively, parts of the scientific community have worked very hard to blur the distinction between these two very very different kinds of "science." For good reason.

While the USA was the wealthiest country in the world with a growing economy no one really cared about the different ways in which we wasted our money. As that situation has changed dramatically and everyone is searching for ways to trim spending, those who do "speculative" science have realized that their forty years of wine and roses are coming to an end. Put in political terms these "welfare queens in white coats" are trying every trick in the book to hang on to their entitlements.

Vast Majority of Scientists Oppose the Supercollider

The facts, well shielded from the public till now, are that a huge majority of scientists including prominent Nobel prize winners in physics (and, of course, in other equally important fields) oppose the supercollider. Sigma Xi, the Research Society of America, made the only known survey ever of the priorities which a representative sample of American scientists would give to various major areas. The SSC came in last with less than three percent, yes, only *about two* percent supporting it. Large numbers of scientists from a wide variety of disciplines oppose the SSC and all Big Science projects. But the most telling are the many criticisms by leading physicists themselves, recounted below, together with the views of influential Congresspersons.

The Department of Enegy regularly publishes the most exaggerated claims regarding the possible spinoffs from the SSC, from improving health to science education. This rebuttal of such claims by A. Penzias, Vice President of Bell Laboratories, a physics Nobel prize winner, was made years ago:

> "I think there has been a fallacious connection made between the present state of particle physics and quantum mechanics. People will say, in the 1930s, who knew that quantum mechanics was going to be good for anything?
>
> "The difference is that in the 1930s, as it was even in the days of the caveman, quantum mechanics applied to everyday experience. You have to do nothing more than urinate into a fire to cause a quantum mechanical effect. There are transitions in salt whose energy-level-difference laws are set by quantum mechanics which say that excited salt atoms are yellow ... That's quantum mechanics, but it deals with a world which is accessible to us in our everyday experience.
>
> "Therefore, let us not pretend that what we experiment [with in particle physics] is, in fact, going to illuminate what happens in that part of the arena of our knowledge and experience that's useful for us."
>
> *Appeared in Scientific American (Japan), Jan. 1992, pp. 24-25.*

Recently, these claims have become so ridiculous that the highest-level members of the physics community and the Congress have both strongly objected to the exaggerations.

Quotations in the scientific press give the flavor of the controversy which is still kept as tightly controlled as possible:

> The dispute, which flared behind the sciences and in congressional testimony began with DOE claims such as: "Already, high-energy physics related to the SSC has had industrial applications in MRI and other technologies." Nicholaas Bloembergen, a Nobel Prize-winning pioneer in the development of MRI, said, "I can assure you that these are spinoffs of small-scale science and not of the SSC."
>
> Later ... Bloembergen re-entered the fray. In a fiery letter he said, "MRI would be live and well today, even if Fermilab had never existed," thundred Bloembergen.
>
> Congressman D. Eckart ridiculed the DOE's claims in laypersons' language:
>
> "We have heard proponents tell us that the Superconducting SuperCollider will cure everything except the heartbreak of psoriasis.* The fact of the matter is that the [SSC] will not make one person well in this country."
>
> * A derisive reference to an obviously exaggerated television commercial.

Then Professor Philip Anderson of Princeton University, another Nobel Prize physicist, opened his testimony to Congress last July with a very clear definitive statement on the key questions thus:

1) *Is the SSC doing the most important, or the only, really fundamental research in the physical sciences?*
   I believe the answer is no.
2) *Will the research done by the SSC have any direct relevance to society or to the ostensible mission of the Department of Energy, namely to conserve and contribute to the nation's energy supply?*
   The answer is no; even its spinoff effect will be negligible.
3) *Are there worthwhile research institutions and projects which are being neglected and starved for money while the SSC is liberally funded?*
   The answer is yes, very many.
4) *Is the SSC so urgent that we have to go ahead with it at any cost?*
   Obviously not.

Damage to Important U.S. R/D

Coming on the heels of the analysis by Congress' own Office of Technology Assessment which shows how seriously small science would be hurt with only modest budget increases, this would appear to doom the SSC in the next year or two. Given the continuing decline in the U.S. economy, the possibility of large increases for all of science certainly appears remote. Given the budget agreement, there can be no illusions but that the rest of U.S. science, including that which is done in industry, will be seriously adversely affected by funding the SSC. The fate of the SSC seems to be running parallel to the ill-fated Clinch River Breeder Reactor, finally killed off by Congress after years and years of uncertainty and a waste of hundreds of millions of dollars.

Damage to Relations with Japan and the International Option

Can anyone seriously doubt in 1993 that ALL Big Science will in the future be done internationally. Why should the U.S. in its weakened economic posture commit itself against this unstoppable historical trend?

If by any incredible means this administration were to force the Japanesegovernment by political pressure to provide $1B+ for the SSC against the strong (unanimous) deliberated consensus of Japanese scientists and engineers, we will have made enemies for all the rest of the U.S. R/D community. Every U.S. R/D policy maker should ask herself or himself that: How would U.S. engineers and scientists feel, if after all our committees had voted against, foreign politicians saddled us with it.

The rest of the world stands ready to cooperate and fund joint R/D in a dozen Big Science fields. The U.S. should cancel the SSC and move to lead this internationalization of Big Science.

Senator BUMPERS. The assumption that anybody who opposes this project is opposed to basic science is a distraction and a diversion. I hate to get into it, and I am not going to get into the fact that the management of this project is an unmitigated disaster.

I am not going to get into the fact that all of this money was spent on parties and whiskeys and flowers and that sort of thing. In the scheme of things, it did not amount to anything. It is simply a manifestation of how totally broken down the cost controls are and how poorly managed the project is, but in the scheme of things, all the money that was spent for parties and liquor and potted plants and so on, that would be about 10 seconds' worth of the money we are spending on this project.

So while, as I say, it is a manifestation of the sort of contempt that some people there must feel for the funding of the thing, in the scheme of things it is not—that in itself is not worth somebody opposing it for.

But when you consider the Secretary of Energy, after doing a performance review study by her team, saying the whole crowd ought to be fired, and you look at 1987, when Admiral Watkins first presented that to the committee, the Energy Committee, and said that it would cost $4.4 billion—I have a considerable interest in the scientific aspects of it despite the fact that we obviously were constrained on how much money would be available, and I remember Admiral Watkins saying in 1990 when he came back before this committee 3 years later that the cost was now—my note says $5.9 billion. As I recall, he said $5.7 billion, and that if it went a dime more than that he would be offboard and would no longer support the collider.

In 1991, we got five different estimates. The super collider lab, SSCL, estimated $7.8 billion, so that is almost $2 billion more than Admiral Watkins had said if it went any higher than that he would be opposed to it, and yet he was over here defending that increase.

The Bush administration through DOE estimated the cost was going to be $8.2 billion—now, this was in 1991—DOE's Energy Research Commission, $8.4 billion, and there are a couple of acronyms here, I do not even know what they are, from DOE. One was $8.9 billion, the other was $11.8 billion.

In 1993, the Department of Energy says the cost is going to be $10.2 billion, and GAO, whom I hope we will also put their report in the record, Mr. Chairman—GAO's study this year says it will be $11.2 billion, but because of a $2 billion mistake in the baseline validation by the project managers in July 1993 say the cost will be $13.46 billion.

[The prepared statement of Mr. Rezendes follows:]

PREPARED STATEMENT OF VICTOR S. REZENDES, DIRECTOR, ENERGY AND SCIENCE ISSUES, RESOURCES, COMMUNITY, AND ECONOMIC DEVELOPMENT DIVISION, GENERAL ACCOUNTING OFFICE

Mr. Chairman and members of the subcommittee, we are pleased to be here today to discuss the Department of Energy's (DOE) Superconducting Super Collider (SSC). My testimony will focus on the current estimated cost of constructing the SSC and on indications that this estimated cost will further increase. The testimony is drawn

from our two recent reports that discuss the cost and schedule status of the SSC,[1] updated to address your concerns about the prime contractor's management and control of the project's baseline cost estimate.

In summary, we found that management problems continue to hinder accurate and timely reporting of the SSC project's cost and status. While the project's total cost cannot be reliably estimated, we feel certain that it will exceed $11 billion. The SSC project's prime contractor, Universities Research Association Inc. (URA), and DOE have been slow to disclose project costs and anticipated cost increases. As a result, the Congress has not received timely and complete information on the project's status and expected cost.

We have previously reported that SSC project costs will exceed $11 billion because some costs were omitted from the baseline cost estimate and because the project's construction schedule is being stretched out an additional 3 years. In January 1991, DOE estimated the project's cost at $8.25 billion, but the agency omitted $1.2 billion in costs to be funded from other sources—$600 million from other federal sources and the rest from nonfederal sources. In addition, the administration has proposed to stretch out the project's completion schedule and reduce the project's planned annual funding. Stretching out the schedule 3 years would cost at least $ 1.6 billion.

We have since found indications that the project's total cost could increase beyond the $11 billion we previously reported. URA has provided us documents identifying potential cost increases of $2 billion, of which URA and DOE officials said at least $600 million are likely. Such an increase could deplete the balance of the project's $843-million budgeted contingency.[2] If the identified potential cost increases materialize and deplete the contingency balance, additional cost increases will either need to be offset by savings from work on other project elements or they will increase the total cost of the project. URA still needs to complete over 80 percent of the project, including elements URA considers to be of high risk, such as the high energy booster accelerator and the production of the superconducting magnets. In addition to potential increases to the project's total cost, the federal share of the project's cost may increase due to a $1.3 billion shortfall in foreign funding.

BACKGROUND

The SSC is intended to be the world's largest particle accelerator—a basic research tool for seeking fundamental knowledge about matter and energy. In 1987, DOE reported to the Congress that the total cost of the SSC project would be an estimated $5.3 billion (in current year dollars), assuming that the project would be completed in 1996.[3] In January 1991, DOE estimated that the SSC would be completed in 1999 at a total cost of $8.25 billion (in current year dollars). About two-thirds of the estimated cost is to be funded by federal sources—$5.6 billion—and one-third by nonfederal sources (primarily the state of Texas and foreign countries). Until recently, DOE had maintained that the cost and schedule estimates reported in January 1991 would be met. By the end of fiscal year 1993, about $1.6 billion will have been invested in the project.

The SSC is being constructed in Ellis County, Texas, about 30 miles south of Dallas. The SSC is composed of three general segments: the injector, collider, and detector. The injector is essentially four interlinked accelerators, each used to increase the energy of the proton beam. The final accelerator in this injection process will be the High Energy Booster, which will be twice as large as any existing particle accelerator. The protons will be injected into the collider, where they will be accelerated in opposite directions into two 54-mile rings. These two beams of protons will be directed to interaction areas, where they will be made to collide at an energy of 40 trillion electron volts (TeV). The principal components of the accelerators are magnets that steer and focus the beams of protons around the rings. As proposed, the SSC will include two large general-purpose detectors that will record the collisions for analysis by physicists.

As the SSC project's prime contractor, URA is to design, construct, and manage the SSC Laboratory. As a nonprofit organization of research universities, URA has had access to the technical talent necessary for designing and building the SSC, but it did not have corporate procedures and support systems for managing such a large

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[1] Federal Research: Super Collider Is Over Budget and Behind Schedule (GAO/RCED-93-87, Feb. 12, 1993) and Federal Research: Super Collider—National Security Benefits, Similar Projects, and Cost (GAO/RCED-93-158, May 14, 1993).

[2] According to DOE, cost increases that result from scope increases or other project enhancements may be funded from DOE's contingency fund. A contingency fund of $843 million is included in DOE's January 1991 baseline cost estimate of $8.25 billion.

[3] Cost estimates in current year dollars are estimates of total costs as spent in the year of expenditure.

project. The project's organization, management, procedures, accounting systems, etc., had to be developed as the program was executed. URA is contractually required to implement a Cost and Schedule Control System and related support systems. The Cost and Schedule Control System, using the baseline cost estimate and other accounting data, periodically reports the status of the cost and schedule of the project, and the project's estimated cost at completion, for management attention. When fully implemented, such a system would show tasks that are ahead of or behind schedule and/or under or over budget. A controlled baseline cost estimate is one of the key elements used in the required Cost and Schedule Control System. A project's baseline cost estimate should include all tasks needed to complete the project, and any change to the baseline estimate should be accounted for by Configuration Control Board established for that purpose. Trends can be extrapolated from the data to produce a range of cost and schedule estimates for the project's completion or for the project's major segments.

URA has awarded subcontracts for conventional construction and for the production and design of project equipment, such as superconducting magnets. Two groups of scientists have been selected to collaborate on the design, assembly, and installation of the two large detectors.

GAO REPORTED THAT THE SSC'S TOTAL COST WILL EXCEED $11 BILLION

In May 1993, I testified that the total estimated cost for constructing the SSC will exceed $11 billion (in current year dollars).[4] DOE's January 1991 estimate of $8.25 billion for the total project cost did not include about $1.2 billion in costs that were expected to be funded by other federal and nonfederal (Texas and foreign countries) sources. In addition, the administration had proposed stretching out the project's completion schedule and reducing the project's planned annual funding. Although the precise impact of this proposal had not been fully analyzed, we noted that stretching out the schedule would increase the cost of the project by at least $1.6 billion. In mid-June 1993, URA was still analyzing the effect of stretching out the schedule and was expected to report its preliminary results to DOE in July 1993.

Some known costs were excluded from DOE's estimate

Our February 1993 report pointed out that DOE's January 1991 cost estimate of $8.25 billion excluded some costs that were expected to be funded from sources other than the DOE appropriation for construction. The baseline $8.25 million estimate does not include a total of over $1.2 billion in costs DOE excluded from its January 1991 estimate. This $1.2 billion includes

- about $543 million for the detectors, for which the SSC project is seeking primarily nonfederal funding ($80 million from other federal sources, $35 million from Texas, $329 from foreign countries, and $99 million from undetermined nonfederal sources);
- about $400 million to be funded by DOE's High Energy Physics Program for laboratory preoperations costs for operating the four injector accelerators prior to commissioning the collider;
- about $118 million through fiscal year 1999 for DOE program direction costs to operate the SSC project office; and
- about $60 million in land costs and $125 million in infrastructure and general support costs, which the state of Texas is contributing.

In commenting on this issue, DOE officials told us that their agency has historically omitted such costs from the estimated cost of its previous accelerator projects; therefore, DOE believes that the omission of such costs from the SSC's cost estimate is consistent with the agency's historical practices. We have reported on this practice of omitting such costs in the past, pointing out that such omissions make it difficult for the Congress to assess the affordability of such projects; consequently, we have recommended that DOE furnish the complete costs of projects to the Congress.[5] DOE officials noted that although some costs were not included in the estimated total project cost, examples of the types of costs excluded were disclosed in DOE's January 1991 cost and schedule baseline report.

Reduced Federal funding will stretch out the schedule and increase costs

DOE's January 1991 cost estimate assumes that the project will be completed in 1999 and that DOE will receive funding according to a timely construction schedule. Our February report cautioned that as the project's peak funding period approaches,

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[4] Federal Research: Superconducting Super Collider Cost and Schedule (GAO/T-RCED-93-47, May 26, 1993).

[5] Nuclear Science: Information on DOE Accelerators Should Be Better Disclosed in the Budget (GAO/RCED-86-79, Apr. 9, 1986).

DOE's funding profile would have to be met or closely approximated if the project is to be completed within the estimated cost and schedule. To illustrate, we referred to an SSC Laboratory study that stated that at an annual federal funding level of $650 million, the SSC project would require an additional 18 months and an additional $570 million (in current year dollars) to complete. In preparing this projection, the SSC Laboratory assumed that all constraints, other than the level of federal funding received, would remain the same as those used in preparing the January 1991 baseline estimate.

At our request, the SSC Laboratory also prepared a profile using a $550 million funding cap. The SSC Laboratory's analysis showed that the project could not be completed at a $550 million federal funding level because overhead costs and reductions in buying power would consume most of the available funds after fiscal year 2000. A DOE official pointed out that this analysis, as well as the analysis for a $650 million funding cap, assumed that the approach for building the SSC would not change. He explained that if it were known that less funding would be available, management could, within limits, restructure the work to fit the available funding. The DOE Project Director added that restructuring the work can deal with funding caps up to a point; at some level, funding would be too low to complete the project.

In April 1993, the President included $640 million for the SSC in his fiscal year 1994 budget request. The federal funding projected for fiscal year 1995 was $551 million, rising slightly each year to $591 million in fiscal year 1997 and increasing to $812 million in fiscal year 1998. The reduction in funding after fiscal year 1994 will increase the project's cost because it will lengthen the time required to complete the project and increase the amount of funding consumed by inflation and overhead costs. As disclosed in the President's budget request, DOE estimated that funding amounts that are below the planning assumptions for fiscal years 1994 through 1998 would increase the SSC's total cost by about $2 billion in current year dollars, plus or minus 20 percent ($1.6 billion to $2.4 billion), and would delay the project's completion by 3 years.

The DOE Project Director requested the SSC Laboratory to prepare a revised baseline budget and schedule by July 1, 1993. As we noted in our May 1993 report, a key assumption in the guidance the Director provided was for the laboratory to assume that funding beyond fiscal year 1998 would be received as necessary to complete the SSC in fiscal year 2003.[6] This assumption will ensure that the SSC Laboratory's analyses will show that the project can be completed with the federal funding levels included in the President's fiscal year 1994 budget request. If, however, annual funding continues to be constrained after fiscal year 1997 at the same level projected in the President's budget request for fiscal years 1995 through 1997, costs may increase indefinitely and the project may never be completed.

As of late June 1993, URA had not completed its revised baseline budget and schedule. According to URA officials, their analysis of the effect of the President's proposed stretch out was slightly behind the original schedule, but the preliminary results of this analysis will be reported to DOE in July 1993.

PROJECT COSTS MAY FURTHER INCREASE

URA's Cost and Schedule Control System for managing the project is now operating, but the data incorporated into the system are still being refined and are not accurate. Until the data are accurate, the system cannot reliably report the project's cost and schedule, nor can it be used to reliably project the total cost. However, we found indications that the project's total cost may increase beyond the $11 billion we reported in May 1993. For example, URA and DOE have been slow to disclose known cost increases, the project's contingency fund balance is overstated, and URA and DOE have identified potential cost increases that could deplete most, if not all, of the remaining contingency fund balance. With over 80 percent of the project to be completed, little or no contingency funds are available to offset additional costs. Furthermore, the lack of accurate information on the project's total estimated cost hinders the Congress in carrying out its oversight responsibilities and making informed decisions.

Problems with the baseline cost estimates and accounting records hinder implementation

As prime contractor, URA is required to maintain the integrity of the baseline by properly recording project changes against the project baseline estimate and incorporating those changes in its Cost and Schedule Control System. Although

[6] According to a DOE official, the SSC Laboratory is to assume the project will be completed at the end of calendar year 2002 (the end of the first quarter of fiscal year 2003).

URA is contractually required to implement such a system, it initially gave low priority to implementing the system. In May 1992, URA began training its managers in the importance of the Cost and Schedule Control System. In December 1992, URA produced its first monthly cost performance report from the system. The monthly reports are not yet producing accurate information primarily because of problems with the project's baseline costs and the allocation of costs among tasks.

As of late June 1993, URA was still trying to reconcile its approved baseline changes with those reported in its Cost and Schedule Control System. URA plans to change the way it has allocated costs so that they can be better compared with the appropriate tasks in the baseline estimate. Without corrections made to the baseline and cost allocations, the reports generated by the Cost and Schedule Control System are also inaccurate and cannot be relied on for monitoring the project's status or progress. A reliable system—with trend analysis showing the estimated cost and schedule for completing the project—will not be available until the system has accurate data to generate accurate reports.

Cost increases not disclosed in a timely manner

URA and DOE have been slow to formally record cost increases as they become known. We found the DOE contingency fund is overstated and potential future costs could outstrip available contingency. Some cost increases were known, but have not been recorded for over two years. DOE and URA managers need complete and timely records in order to effectively manage the project, and the Congress needs full disclosure of costs for carrying out its oversight responsibilities.

Of the $843 million in the baseline for contingencies, DOE had approved the use of about $48 million, or about 6 percent, as of June 1993; however, this does not reflect the total additional known costs that the project is experiencing. In May 1993, URA acknowledged that a number of approved and pending project changes that require additional funding had not been posted. In accounting for unposted changes, URA acknowledged that the SSC project had a negative balance of $53 million in its management reserve account.[7] Furthermore, we found that URA had an additional $22 million in approved project changes and errors in recording that were to be charged against management reserve. In effect, this management reserve of negative $75 million is an undisclosed claim against DOE's contingency.

Other cost increases were identified by URA, but were not recorded in the baseline cost estimate. For example, the January 1991 baseline did not reflect some of the costs associated with having a leader-follower approach for contracting for the superconducting dipole magnets to be used for steering the proton beams around the collider rings. In July 1991, URA awarded two superconducting magnet development contracts for which the award amounts totaled about $117 million over the magnet baseline cost estimate. URA did not adjust the baseline estimate to reflect this increase. According to URA officials, this was because the increase will be offset by anticipated savings resulting from increased competition for the subcontracts for the magnets to be built during the full-rate production phase. More recent URA studies indicate that these savings may not be realized. We believe that URA should have recognized the increase in its estimates as soon as it was known and, if appropriate, separately recognized any anticipated savings in its estimate. In April 1993, URA began formally recognizing these costs.

Indications are that other cost increases are likely. About 2 weeks ago, URA provided us documents that identified potential cost increases totaling about $2 billion. In discussing this issue, URA and DOE officials advised us that the documents were of a very preliminary nature and that much of the increased costs included in the $2 billion had since been revised downward. URA and DOE officials estimated that the more realistic potential cost increase, aside from increases due to the stretch out, is about $600 million. Many of the cost increases identified are a result of underestimates in the baseline cost estimate. For example, the baseline cost estimate for the URA's labor costs was underestimated by about $200 million, according to the DOE Project Director. He advised us that the administrative costs for managing the SSC Laboratory are much higher than originally estimated.

These officials further advised us that some of the increases may be offset by savings totaling up to $200 million. Such savings would result from increased contractor competition and from tunneling contracts being awarded under baseline. We have not yet verified the potential amounts of the increases or savings.

If the identified potential cost increases materialize, they would consume most, if not all, of the total funds available in the project's contingency. Without a

[7] According to DOE, cost increases from overruns are funded from URA's management reserve fund. Funds for the reserve are not provided for in DOE's January 1991 baseline cost estimate of $8.25 billion, but are intended to be generated from project savings.

contingency fund balance, any additional increase in cost would increase the project's total cost unless additional savings can be found to offset that increase. Future cost increases can be expected because over 80 percent of the project remains to be built, and many of the high technical and cost risk items such as High Energy Booster accelerator, the superconducting magnet production, and the collider installation remain to be completed.

DECISION ON WHETHER TO RELY ON FOREIGN CONTRIBUTIONS NEEDS TO BE MADE

In addition to the total cost of the project increasing, the federal share of the cost may increase. DOE still needs nearly all of the $1.7 billion in foreign contributions it has been seeking if it is to meet the schedule and cost goals it established as part of its January 1991 estimate. In December 1992, we reported that only about $15 million in foreign contributions had been received.[8] We pointed out that the Congress faced a critical decision point for its funding of the SSC.

For fiscal year 1994, the SSC project's funding profile shows that about $250 million in foreign contributions was needed. We reported in 1992 that without a major contribution from Japan in fiscal year 1994, the Congress would, in all likelihood, be faced with deciding whether to increase U.S. funding to make up for the shortfall in foreign contributions or to let the project's schedule slip further. A 1-year slip in the project's schedule could increase the SSC's cost by about $400 million in current year dollars. Furthermore, we reported that the Congress would have to decide whether it would be willing to ask the U.S. taxpayer to bear a substantially larger portion of the SSC's cost in future years if Japan decided not to contribute to the project.

We advised the Congress that, as part of its consideration of fiscal year 1994 funding for the SSC, it should require DOE to provide the most complete, accurate, and up-to-date information available on the status of the agency's efforts to obtain contributions for the SSC from Japan and other foreign countries.

In a letter dated January 14, 1993, DOE provided the Congress with updated information on the funding status of the SSC project, including information on the extent of foreign contributions anticipated. DOE acknowledged that without a significant contribution from Japan, it was highly doubtful that the $1.7 billion foreign funding goal could be met; DOE was confident that foreign commitments of only $400 million could be obtained by fiscal year 1999.

CONCLUSIONS

Since the SSC was first proposed to the Congress in 1987, estimated costs have more than doubled—from $5.3 billion to more than $11 billion. We have since found indications that the cost could increase further. Potential cost increases that URA has identified could deplete the project's contingency fund with more than 80 percent of the project yet to be built. With much of the highly technical work still to be done, it seems unlikely that the project will be completed without incurring any additional cost increases, or that project savings will be sufficient to offset these increases. In addition, because URA and DOE have been slow to report cost increases, the Congress does not have timely and complete information for carrying out its oversight responsibilities and making informed decisions.

Furthermore, to preclude the SSC's cost from significantly increasing beyond the $11 billion estimate, annual funding levels beyond fiscal year 1998 would need to be increased dramatically over those projected in the President's budget for fiscal years 1995 through 1997. Following DOE's guidance, the SSC Laboratory, in its current study of the impact of the President's proposed project funding, assumes that funding will increase in fiscal year 1998 and will not be constrained from fiscal year 1999 through the project's completion at the end of calendar year 2002. Unless the budget deficit is markedly reduced, such an assumption could prove unrealistic. Continued funding at the level projected for fiscal years 1995 through 1997 could lead to inflation and overhead costs consuming all available funding, thereby hindering the ability to complete construction.

The SSC project has reached a crossroads at which key funding decisions need to be made. At the end of fiscal year 1993, about $1.6 billion will have been invested in the project. Currently, the SSC is over budget and behind schedule, and costs are expected to further increase as a result of funding constraints. Moreover, the congressional limit of $5.6 billion for the federal share of the project's cost must increase. DOE currently expects to receive only $1.4 billion from nonfederal sources—$400 from foreign sources and $1 billion from Texas. As a result, to

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[8] Federal Research: Foreign Contributions to the Superconducting Super Collider (GAO/RCED-93-75, Dec. 30, 1992).

complete the project the Congress will have to substantially increase the federal share of funding.

Mr. Chairman, this concludes my prepared remarks. I would be pleased to respond to any questions from the Subcommittee at this time.

Senator BUMPERS. Since 1987, 6 years, the cost of this project has tripled and will almost certainly quadruple and quintuple before it is completed, and if that were all there was to it, one might still say, well, perhaps it is worth it, but there is one other little item. It costs $500 million a year to operate this project, and it costs 4½ percent a year in interest to pay for all the money we are going to borrow to build it, so the 20-year cost is $36 billion.

Now, the $400 million or $500 million or $600 million that we are going to put in for 1994, that seems like nothing compared to that.

All I am saying is that that is an absolutely staggering prohibitive cost at a time when we are cutting Medicare $56 billion over the next 5 years. We are cutting Medicaid something like $12 or $15 billion. And all the great spending cutters in the U.S. Senate—we have got to cut spending; I cannot vote for this bill because it has got taxes in it; we have got to cut spending—you watch them jump under the desk when I offer this amendment. And on the space station, which has far less merit than this project, watch them jump under their desks.

They say we have got to cut entitlements. That is a really nice buzzword for everybody to hide behind. When you start saying you want to kick Aunt Suzie out of the nursing home—that is not what they had in mind. You want to freeze Social Security COLA's? That is not what they had in mind. What do they have in mind? Politics.

And so, Mr. Chairman, members of the committee, this will be the fifth year that I have tried to convince the U.S. Senate that this project is simply not meritorious enough to spend that kind of money on. In a perfect world, I would be for it. Unhappily, we do not live in a perfect world.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Bumpers, just one rejoinder, and that is on the question of cancer. This project is not primarily about cancer. We have never claimed that. But it does have a proton beam. Some 9,000 people have been treated at Fermi Lab and our lab in California, and thousands would be treated with the proton beam here, although again, that is a small part of the project.

Senator Nickles.

Senator NICKLES. Pass.

The CHAIRMAN. Senator Craig.

Senator CRAIG. He was here before me.

The CHAIRMAN. Senator Bennett.

Senator BENNETT. As usual, Mr. Chairman, I am here to learn. So I will forgo an opening statement.

STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM IDAHO

Senator CRAIG. Mr. Chairman, just having walked in, I would like to make a brief comment. Mr. Chairman, I, too, am here to increase my knowledge of this very important research project that this Government and this country is involved in. I have supported

it in the past, and will, as far as I know now, continue to support it, at least based on all of the material that is currently available to us.

I really do believe that great nations are nations that can find it within their wherewithal to push the envelope of science, and must continue to do so. I am growing increasingly alarmed at a Nation whose Government chooses to reduce and progressively reduce its outlays in science, research, research development, technology, to fund the necessary day-to-day kinds of events that we should suggest to the average citizen is partly their responsibility.

We know that there are certain types of concentrated science research projects that we cannot ask any one group or any one industry to do. Clearly, in the early sixties we decided that in space we would become a leader, and we did. And this Nation has reaped the benefits of that kind of government direction and guidance in this kind of technology ever since.

I believe that whether it is a Superconducting Super Collider or whether it is IFR or whether it is any other of those very important kinds of programs that cause us to look into the future, that somehow this Government has to provide that kind of funding.

Now, I think that, as probably one of the more conservative members of the U.S. Congress, I frankly believe, Mr. Chairman, this Congress and its Senate has its priorities improperly directed. And my vote will represent that. And I would take money away from other programs and put money in these kinds of programs to reap the long-term benefit for the good of our society and for the good of the world. That is how my vote will be reflected as we deal with these kinds of issues.

But I do believe that we constantly must make the case, as I hope this committee and those who testify today will continue to make the case, that we can afford to spend money in these areas and the reason why we should be able to do that. Without that, then, my ability to be able to support it increasingly wanes. So it is a joint responsibility of all ours to do so.

The CHAIRMAN. Thank you.

Dr. Gibbons, we are ready for your testimony.

STATEMENT OF DR. JOHN H. GIBBONS, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Dr. GIBBONS. Thank you Mr. Chairman, members of the committee. I have submitted my written testimony for the record, but I would like to go through it with you this morning, because I think we are facing——

Senator BUMPERS. Dr. Gibbons, for those of us who are old and hard of hearing, would you pull the microphone a little closer, please?

Dr. GIBBONS. How is this, Senator?

Senator BUMPERS. That is much better, thank you.

Dr. GIBBONS. I think, as so eloquently displayed in your opening comments, we do face a tough issue as we become more realistic about our resources and how those public investments are to be made in the coming years. And I am pleased to bring to you a

statement this morning that will, at the bottom line, reiterate the administration's position taken earlier this year on this issue.

We do feel that America's future depends on continued long-term support of research and development in science and technology. It is a fundamental tenet of the administration and one I know shared by all of you. At the same time, we are talking about big science here, and big science is a two-way squeeze. One squeeze is the traditional concern about big science versus little science that has been, I think, a part of our agenda for at least 2 decades now, enumerated early on by my ex-boss at Oak Ridge, Alvin Weinberg.

That is one squeeze, the tradeoff between large pieces of equipment such as the SSC, which is the world's largest instrument ever built, and another squeeze is this question of public investment. How do we spend our public dollars in preparing to answer not only today's needs but to prepare for tomorrow's opportunities? It is those two squeezes that I think we have to wrestle with today.

Weinberg years ago talked about big science and criteria for choice in big science. Additional criteria come in to play when the dollars grow, as I think were so well reflected in your comments this morning. And there are three criteria—and I would like to talk about those three criteria with respect to the SSC. One is the question of scientific merit, a second is of social merit, and finally, technological merit.

The SSC does promise an answer to the question that has driven human progress for centuries; namely, how does the world work? What are the principles that shape and govern the physical universe? The search for an underlying simplicity and coherence in what seems to be a very complex world first led the ancient Greeks to the theories of atoms. And the inquiry continues today in a world constantly revolutionized by discoveries in science and advances in technology.

The search led Isaac Newton to discern the underlying orderliness of the world and to the laws of mechanics and gravity and the mathematical principles that now are used to design our machines, drive our rockets, and in general, to sustain the technological world. It led Michael Faraday and others to a study of electricity and magnetism that ultimately electrified the world with radio, television, motors, and even cellular phones.

It captivated Curie and Einstein, Wooler, Heisenberg, Shirlinger, Rutherford, and many others in the search for the principles of atomic structure in quantum mechanics and absolutely unanticipated by them brought us nuclear energy, magnetic resonance imaging which saves how many lives we cannot really say, but many, and a host of other medical treatment methodologies, lasers, and other technologies too innumerable to recount, and yet the original work was carried out on the basis of trying to figure out not how to cure cancer, but how the world works.

The SSC is the culmination of several millennia, then, of human inquiry into the basic constituents of nature. We have gone smaller and smaller in dimensions in terms of our research, and that in turn requires higher and higher energy in order to get there. And that, in turn, requires bigger and bigger devices.

The instrument known as the Superconducting Super Collider will be used by scientists from around the globe to pursue these research venues. It will be the unquestioned premiere global flagship for research at the high energy frontier.

Scientists will use the SSC to examine why the known elementary particles have masses the way they do. We have no theory to explain why quarks are heavier than electrons or for why these particles even have mass at all. It is a tantalizing question, a part of the set of questions that began, I guess, when we first looked up to the heavens and asked what in the world are all those things up there and what is our place in it.

Since the 1960's, physicists have made a lot of progress by combining theory and experiment to explain and systematize these fundamental building blocks of nature, particles, particles that combine and recombine to form atoms and nuclei, and despite the impressive progress, the key ingredient in our understanding of a predicted heavy particle known as the Higgs-boson remains to be tested experimentally. That is, to be observed, because the realm in which this particle lies, we believe, requires unprecedented energy, because that is the nature of the particle. And with unprecedented energy, also very precise measurements.

In the energy range the SSC is designed to probe, we would expect to resolve the prediction of the Higgs-boson, and we will likely run into unanticipated findings, as well.

It is important to note that whenever more powerful accelerators come on line, totally unexpected things invariably occur. The Stanford linear accelerator and the Brookhaven National Laboratory accelerator unexpectedly discovered in the seventies a family of new particles known as J, psi, and tau particles that completely revamped our understanding of particle physics.

Even the most confident physicist today knows that they cannot predict everything interesting that will happen with the SSC. Some of its greatest discoveries will undoubtedly be things that we cannot even begin to anticipate today. In other words, even though we know how to design and build this accelerator, we do not know exactly what is going to happen in terms of the results we will discover.

Nils Bohr once said that it is a very difficult thing to make a successful prediction, especially if it has to do with the future. In this case, it is difficult to make a full prediction about what will happen, even in terms of how we come to understand better the nature of the very material we are composed of.

The SSC will also help to resolve many other unanswered questions beside the Higgs-boson. For example, physicists has had great success in showing that forces seemingly quite different are, in fact, two aspects of the same force. 19th century physicist James Clerk Maxwell showed that the electric force and magnetism were actually two aspects of but one kind of force, so-called electromagnetic force.

Physicists working over the past 30 years also devised a way to unify electromagnetism with the force responsible for radioactivity known as the weak force. And this is now integrated into what is known as the electroweak force. That is, our understanding of the principles underlying the way the world works is evolving and

coming forward, and some of the most critical progress has been even within the last 30 years.

The SSC may help physicists to unify electromagnetism and the electroweak force with another known force in nature, the so-called strong force which holds the nuclei of atoms together, and perhaps also help us understand the link between those forces and the force of gravity. If so, the SSC would enable a major step forward to what physicists have described as the grand unification theory or the theory of everything, a thing that Leon Letterman, another participant in this adventure, has described as a theory of the universe that is succinct enough to be put on a T-shirt such as Einstein's equations or Maxwell's equations can be.

A number of fundamental questions about the nature of the universe remain unanswered. Why, for example, is not the universe populated with antiparticles as well as particles, positrons as well as electrons? Why does the universe exhibit the forms that astronomers see in their telescopes? The galaxies, including our own, the Milky Way, are clumped together in gigantic structures that look like immense bubbles in the universe.

This large scale structure seems to have originated in just millionths of a microsecond after the big bang that created the universe, and it seems to be related to the property of elementary particles. And thus, we see one of the tests of this big science is that it integrates from the smallest—that is, the nature of these tiny particles, to the very largest, namely, the nature of our universe, cosmology and astrophysics, at one and at the same time.

By creating some of the conditions that occurred very, very early on in the big bang, the SSC will help reveal why the universe, including our small corner of it, took on its current form. One criterion for choice, as I mentioned, of big science is the question, "Does it illuminate other disciplines?" And I would reiterate that the SSC simultaneously addresses particle physics, the smallest end of the scale, with cosmology and astrophysics at the largest end of the scale.

It will help keep the United States at the frontiers of particle physics and of the human exploration of the unknown. It will embody the most noble aspects of human curiosity and will be a sign to all, not only now but to future generations, that we intend to maintain ourselves at the vanguard of scientific discovery.

Well, what about social merit? Often, a scientific activity has direct and immediate social impacts that precede any technological spinoffs or advances in scientific theory. Questions about physics have fascinated people from all walks of life and obviously engage us in many unexpected ways.

So amazing did the so-called "big bang" theory seem to the main characters of one of my favorite comic strip, Calvin and Hobbs, and so pedestrian was the scientists name for it—big bang—that Calvin and Hobbs suggested calling it the "horrendous space kablooey," and immediately generated a worldwide contest on what one should call this event. A wonderful writer from Arkansas, Ellen Gilchrest, mesmerized radio audiences for months with her musings on physics and entitled a book of popular short stories called, "Light Can Be Both Wave and Particle."

The questions they posed reflect a timeless universal eagerness to embrace and wrestle with cosmology, with theoretical physics and its implications for how things work, for our daily lives, how we think about ourselves and the world in which we are a part.

Fortunately, some people also actually choose to make a serious study of particle physics or so-called high energy physics. High energy physics attracts some of the best and brightest minds to science, and the SSC, sort of like a supermagnet, will attract thousands of young scientists and engineers, not only from our own ranks but from around the globe.

In the future, many of them will stay in physics research, but if the pattern of history holds out, the majority are likely to apply their education and their experiences in new ways to diverse new problems. We have much to gain from the inspiration that the SSC offers gifted individuals. We must support the fields of scientific inquiry that will challenge their most creative minds.

An important social impact of the SSC is its contribution to the education and training of individuals that are likely to influence the course of human history, not only in science but in other endeavors. If I had more time with you this morning I would love to tell you about some of the people who have gone through the halls of particle physics research, have emerged, and then used those skills and orientations obtained to make major contributions in other areas of science and social service.

The SSC, if conducted as an international collaborative enterprise, will play a major role in furthering international understanding and cooperation. This not only has important social impacts, but I believe has important economic and security impacts.

High energy physics is one of those fields where the scientific community must mount decades-long, expensive megaprojects to probe the remaining fundamental secrets of the universe. In years gone by, we and a number of other nations made unilateral commitments to megaprojects, and we absorbed the costs of such projects in our own growing R&D budgets. But that is no longer possible, as so clearly pointed out by you gentlemen this morning.

It is not possible for two reasons. One, we have major budget constraints imposed by the realization that we have already borrowed too much money from our children. R&D funding cannot grow as it did in the past. The second constraint is that big science and big technology projects are so expensive, driven by the very nature of things that we are trying to investigate, that no one nation, no matter how wealthy, can afford to go it alone.

Well, looking back, it is easy to question the wisdom, then, of the decision made by the United States in the eighties to launch the SSC as a solely national effort. Although it is late in the game, the administration plans to work with Congress to use every sensible measure to transform the SSC into a more completely international venture.

Equities between nations must be addressed in this effort, and internationalization of any given project, especially one as big as the SSC, cannot be considered in isolation. It will probably make sense to put other big science projects on the table for discussion

at that time. Projects in fusion, nuclear physics, space, as well as other high energy physics experiments are among those candidates.

Let me assure the committee that we will approach this challenge very carefully, and will work closely with the Congress and our foreign counterparts to bring this concept of shared and equitable responsibility for big science projects to full implementation. The whole world, we believe, will benefit if together we can be successful.

Finally, concerning the technological merits of the Superconducting Super Collider, we know it is a huge project. It is at the cutting edge of technology, as well as science. It is the largest scientific instrument ever built. It will undoubtedly result in some inventions that will be commercialized and pay back some fraction of its costs and its operating budget.

For example, the particle accelerators originally developed to conduct physics experiments are now used in areas as varied as medicine and the manufacturing of high resolution integrated circuits. We can anticipate that construction and operation of the SSC will result in important improvements in superconducting magnets, tunnel drilling, precision surveying, complex systems analysis and controls, data acquisition and analysis systems, and will yield totally unexpected new technologies.

To sum up, the Clinton administration does continue to support the Superconducting Super Collider for the reasons I have just enumerated. Support for the SSC shows other nations that the United States will not forsake its leadership in the world scientific community, a leadership that is cast increasingly in an international context.

Support for the SSC reminds U.S. citizens that the pursuit of scientific and technological excellence has created the world as we know it today and forms the most essential basis for future economic prosperity. And support for the SSC promises our children, at a time when we otherwise seem to be growing shortsighted, that we will make the long-term investments in education, research, and in the pursuit of knowledge that will ensure a brighter future for them.

The most important benefits of the increased understanding that will be gained from the SSC may not be known for a generation, certainly not for a decade. We can, however, be certain that important benefits will result simply from making that effort. The SSC project will stimulate technologies in many areas critical to our national economy. It will produce critical employment and educational opportunities for literally thousands of young engineers and scientists from around the country, and will attract to our shores, importantly we believe, some of the brightest and most creative minds from around the world.

Abandoning the SSC at this point would signal that the United States is compromising its position of leadership in basic science, a position unquestioned for generations. These are tough economic times, as you know even better than the rest of us that only try to help you because we cannot vote except for voting you in or out of office. It is your most serious responsibility to vote on issues such as SSC.

As the administration has espoused this past spring, we support this project as part of our broad investment package in science and technology. The same administration that is committed to deficit reduction supports this as an important investment. Our support requires making sure, of course, that the project is well managed and that the Congress and the administration is kept appraised of the full costs, as well as the anticipated benefits of the program. The stretched-out funding proposed by the administration will allow better control of project costs, we hope. It will lower annual costs for the construction phase and it will allow, importantly, more time to enhance the internationalization of this field of science.

The scientific, social, and technological merits then, gentlemen, of this SSC I believe justify your continued support of the project. We ask you to support this important and challenging effort, and I would be happy to respond to your questions.

Thank you.

[The prepared statement of Dr. Gibbons follows:]

PREPARED STATEMENT OF DR. JOHN H. GIBBONS, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Mr. Chairman, Members of the Committee, thank you for the opportunity to appear before you today in support of the Superconducting Super Collider (SSC). The Clinton Administration believes America's future depends on continued, long-term support of research and development in science and technology. In an era when science projects must compete among themselves and also with many worthwhile programs outside the scientific community for scarce resources, the SSC fulfills three criteria for choice, first mapped out by my ex-boss at the Oak Ridge National Laboratory, Alvin Weinberg, that speak strongly for its continuation. It has scientific merit; it has social merit; and it has technological merit.

SCIENTIFIC MERIT OF THE SUPERCONDUCTING SUPER COLLIDER

The SSC promises an answer to the question that has driven human progress for centuries: How does the world work? The search for an underlying simplicity and coherence in a complex world led the ancient Greeks to the theory of "atoms," a theory that, when proved, changed civilization forever with nuclear energy, nuclear medicine, and, of course, terrifying nuclear weapons. It led Isaac Newton to the laws of mechanics and gravity and the mathematical principles that now sustain our technological world. It led Michael Faraday through a study of electricity and magnetism that ultimately "electrified" the world. The SSC is the culmination of several millennia of human inquiry into the basic constituents of nature.

The device known as the SSC will be used by scientists from around the globe to pursue many research venues. It will be the unquestioned global flagship for research at the high energy frontier. Scientists will use the SSC to examine why the known elementary particles—electrons and quarks—have the masses they do. Physicists have no theory to explain why quarks are heavier than electrons, or for why these particles have mass at all.

Since the 1960's, physicists have made great progress by combining theory and empiricism to explain and systematize the fundamental building blocks—particles—that combine to form nuclei and atoms. Despite the impressive progress, a key ingredient in our understanding (a heavy particle known as the Higgs boson) remains to be tested experimentally, i.e., to be observed. Locating this ingredient requires unprecedented energy and precise measurements. In actuality, there may be a number of Higgs bosons or entirely different families of particles. In the energy range the SSC is designed to probe, we expect to resolve the prediction of Higgs, and we will likely run into some unanticipated findings as well.

The SSC will also help resolve many other unanswered questions in science in the process of finding new particles. For example, physics has had great success in showing that forces seemingly quite different are in fact two aspects of a single force. Nineteenth century physicist James Clerk Maxwell showed that the electric force and magnetism are actually two aspects of a single force, electromagnetism. Physicists working over the past 30 years also devised a way to unify electromagnetism with the force responsible for radioactivity, known as the weak force, yielding the electroweak force. The SSC may help physicists to unify

electromagnetism and the weak force with another known force in nature, the strong force, which holds the nuclei of atoms together, and, perhaps, also with the force of gravity. If so, the SSC will enable a major step toward what physicists refer to as the "grand unification" theory or the "theory of everything"—what Leon Lederman has described as a theory of the universe succinct enough to put on a tee shirt.

A number of fundamental questions about the universe remain unanswered. Why, for example, is the universe not populated with antiparticles as well as particles? The SSC will be a copious source of the b-quarks physicists wish to study for clues to that mystery. Why does the universe exhibit the form astronomers see in their telescopes? The galaxies, including our Milky Way, are clumped together in gigantic structures that look like immense bubbles in the universe. This large-scale structure seems to have originated just millionths of a microsecond after the Big Bang that created the universe, and it seems to be related to the properties of elementary particles. By recreating some of the conditions that occurred very, very early in the Big Bang, the SSC will help reveal why the universe, including our small corner of it, took its current form.

Finally, it is important to note that whenever more powerful accelerators come on line, totally unexpected things invariably occur. The Stanford Linear Accelerator and Brookhaven National Laboratory unexpectedly discovered, in the 1970's, a family of new particles known as the J, psi, and tau particles that completely revamped our understanding of particle physics. Even the most confident physicists know they cannot predict everything interesting that will happen with the SSC. Some its greatest discoveries will undoubtedly be things we cannot even begin to anticipate today.

The SSC will keep the United States at the frontiers of particle physics and of human exploration of the unknown. It will embody the most noble aspects of human curiosity and will be a sign to all that the United States intends to remain at the vanguard of scientific discovery.

SOCIAL MERIT OF THE SUPERCONDUCTING SUPER COLLIDER

Often, a scientific activity has direct and immediate social impacts that precede any technological spinoffs or advances in scientific theory. Questions about physics fascinate people from all walks of life and engage us in unexpected ways. So amazing did the Big Bang seem to the main characters of the comic strip Calvin and Hobbs—and so pedestrian scientists' name for it—they suggested calling it "The Horrendous Space Kablooie" and immediately generated a worldwide contest! A wonderful writer from Arkansas, Ellen Gilchrist, mesmerized radio audiences for months with her musings on physics and entitled a popular book of short stories "Light Can Be Both Wave and Particle." The questions they posed reveal a universal eagerness to embrace and wrestle with theoretical physics and its implications for our daily lives—how we think about ourselves and the world of which we are a part.

Fortunately, some people actually choose to make a serious study of particle, or high energy, physics. High energy physics attracts some of the best and brightest minds to science, and the SSC, like a super magnet, will attract young physicists from around the globe. In the future, many of them will stay in physics research—pushing us ever closer to an explanation for the inner workings of the universe—but if the pattern of history holds, the majority are likely to apply their education and experiences in new ways to diverse new problems. We have much to gain from the inspiration the SSC offers gifted individuals. We must support the fields of scientific inquiry that challenge the most creative minds. An important social impact of the SSC is its contribution to the education and training of individuals likely to influence the course of human history through science and other endeavors.

The SSC, if conducted as an international collaborative enterprise, will play a role in furthering international understanding, another important social impact. High energy physics is one of those fields where the scientific community must mount decades-long, expensive "megaprojects" to probe the remaining fundamental secrets of the universe. In years gone by, we and a number of other nations made unilateral commitments to megaprojects and absorbed the costs in our growing R&D budgets. But this is no longer possible—for two reasons. First, we face major budget constraints, imposed by the realization that we've already borrowed too much money from our children; R&D funding cannot grow as it did in the past. Second, big science (and big technology) projects are so expensive that no one nation—no matter how wealthy—can afford to go it alone.

Strong beginnings have already been made to internationalize big science projects. Last year, with strong U.S. leadership, the Organization for Economic Co-operation

and Development (OECD) established a "Megascience Forum," to examine megaprojects in all areas of science and to provide effective means for analysis and communication between diverse scientific communities and governments. The OECD Forum is a solid step toward a regime where all big science and technology projects are truly international.

Looking back, it is easy to question the wisdom of the decision made by the United States to launch the SSC as a national, rather than international, effort. Although it is late in the game, the Administration plans to use every feasible measure to transform the SSC into a true international venture. Equities between nations must be addressed in this effort, and internationalization of any given project, especially one as large as the SSC, cannot be considered in isolation. It will probably be necessary and sensible to put other big science projects on the table for discussion at the same time. Projects in fusion, nuclear physics, and space, as well as other high energy physics experiments, are among the candidates. Let me assure this Committee that we will approach this challenge very carefully, and will work closely with the Congress and our foreign counterparts to bring this concept of shared and equitable responsibility for big science projects to the implementation stage. The whole world will benefit if we are successful.

TECHNOLOGICAL MERIT OF THE SUPERCONDUCTING SUPER COLLIDER

The SSC is a huge project at the cutting edge of technology. It will undoubtedly result in some inventions that will be commercialized and pay back some fraction of its costs and operating budget. For example, the particle accelerators originally developed to conduct physics experiments are now used in areas as varied as medicine and the manufacture of integrated circuits. Research performed for Fermilab's Tevatron I accelerator is having spinoffs for medicine via superconducting magnets, independently of new research on high-temperature superconductors. We can anticipate that construction and operation of the SSC will result in important improvements in superconductivity, tunnel drilling, precision surveying, and data acquisition systems and yield totally unexpected new technologies.

CLINTON ADMINISTRATION SUPPORT FOR THE SUPERCONDUCTING SUPER COLLIDER

Mr. Chairman, the Clinton Administration supports construction and operation of the SSC for the reasons I have just described. Support for the SSC:

1. Shows other nations the United States will not forsake its leadership of the world scientific community, a leadership that is cast increasingly in an international context.
2. Reminds U.S. citizens that the pursuit of scientific and technological excellence has created the world we know today and forms the basis for economic prosperity.
3. Promises our children we will make the long-term investments in education and research that will ensure a bright future for them.

The most important benefits of the increased understanding gained from the SSC may not be known for a generation. We can, however, be certain important benefits will result simply from making the effort. The SSC project will stimulate technologies in many areas critical for the health of the U.S. economy. The superconductor technologies developed for the project's magnets will stimulate production of a material that will be critical for ensuring the competitiveness of U.S. manufacturers, for improving medical care, and a variety of other purposes. The SSC will also produce critical employment and educational opportunities for thousands of young engineers and scientists around the country and will attract to our shores some of the brightest and most creative minds from around the world.

Abandoning the SSC at this point would signal that the United States is compromising its position of leadership in basic science—a position unquestioned for generations. These are tough economic times, yet our Administration supports this project as part of its broad investment package in science and technology. Our support requires making sure that the project is well managed and that the Congress is kept apprised of the full costs and of the anticipated benefits of the program. The SSC previously had an unstable funding profile. The stretched-out funding proposed by our Administration of $640 million in FY 94 will allow better control of project costs and more time to enhance internationalization of this field of science.

The scientific, social, and technological merit of the SSC justify your continued support for this project. I ask you to support this important and challenging effort. I would be happy to answer your questions.

The CHAIRMAN. Dr. Gibbons, I want to congratulate you on an excellent statement. I think you have said it all. I invite my colleagues to consider the fact that we have another very distinguished panel, along with some votes on the floor today.

I would urge them, particularly my good friend Senator Hollings, that the question of national labs, which is a vital question I know to you and to our two New Mexico Senators and other members of this committee, is vitally interesting and I hope an issue on which we can get agreement between you and me and us in our committees. I would hope we could defer that question to another day, because every issue brought up, you have to clear that up, and we could spend our whole time talking about national labs and their issue.

Nevertheless, my friend from South Carolina is recognized to ask whatever he wishes. Senator Hollings.

Senator HOLLINGS. I will be very brief. Incidentally too, since I said we are on the cutting edge of paying the bill, I recommended to the President, have proposed for several years now a 5 percent value-added tax across the board, because we need the revenues of that kind. If we could have those kind of revenues, then we could pay for the super collider and the space station and the Osprey and the intelligence and advanced solid rocket motor.

I have got a long list of things that I have got to talk about with Dr. Gibbons.

Dr. Gibbons, with respect to the assignment to the Secretary of Energy of the development and commercialization of, let us say, space technologies, do you think that the Secretary of Energy should be assigned that role?

Dr. GIBBONS. Mr. Chairman, I want to make it clear that the administration strongly supports S. 4, the competitiveness legislation under your leadership. We are also interested in the companion or the associated bill, S. 473. But we are seeking a clear definition of the role of the national labs in contributing to the competitiveness challenge before us.

We are concerned, and are committed that the Department of Commerce be strengthened to work jointly with industry as we shift our whole Federal R&D package from a cold-war-defense-dominated situation, to one that pays much more attention to the civilian side of the equation. And under that plan, the NIST, the National Institute for Standards and Technology, is going to grow dramatically, perhaps more than any other part of the budgets we propose.

At the same time, we want to assure that the resources and expertise available in the whole Federal family be brought to bear on this most pressing and important issue. And to that extent, we do support the use of the national labs, the DOE labs, in terms of their capabilities in pursuing the core missions which have more to do, as has been pointed out, with energy, with environment, with those things in which they have been engaged for a long time.

I do not think that it is at all proposed that the Energy labs suddenly become our space labs. So in direct answer to that question, I certainly would agree with you. And I think the language that the administration is developing to clarify this point with respect to S. 473 will make that as clear as we can.

Senator HOLLINGS. You are going to make it clear. That is what I am trying to do, because you finally came down. In other words, we got NASA, and if we are going to now get the Department of Energy also into space, then, you are creating a shopping mall for, specifically, advanced technologies.

Dr. GIBBONS. At the same time, it takes energy to get into space so it is hard to draw sharp lines between these missions. They are inherently interwoven, and our role for the administration, I believe, in good faith response to Congress' concern, is to assure that those various resources be properly interweaved in a way that maximizes the value of the Federal involvement here in achieving these goals.

Senator HOLLINGS. Well, how about human health sciences then? What about NIH, do you want to give it to the Department of Energy? I mean maybe I can make that one a clearcut decision. If you cannot do it with space and NASA and energy, maybe you can do it with NIH. Do you think we ought to do the research for health now in the Department of Energy?

Dr. GIBBONS. You know, there was an economist who once said that there is no problem, however complicated, which if you examine it carefully enough does not become more complicated.

[Laughter.]

Dr. GIBBONS. And I think NIH brings that to mind. For example, magnetic resonance imaging which is a very important medical diagnostic tool—that came straight out of nuclear physics in the Department of Energy by nuclear magnetic resonance. It is clear that NIH has the fundamental role primary lead in health-related research. At the same time, that is not to say that there are not health related kinds of activities that arise from fundamental investigations in physics and other sciences. So it is tough for me to give you a straight answer.

Senator HOLLINGS. Good gosh. You are creating a shopping mall. What about textiles? If I want to develop technology, manufacturing technologies and the commercialization of that technology for textiles, will you go to the Department of Energy or the Department of Commerce?

Dr. GIBBONS. Well, I would first hope that we would listen very carefully to what the textile industry has to say about their concerns and their perceived shortcomings, and then I would see how, to the extent possible, we could respond to those concerns and interests in ways that reflect public interest.

Senator HOLLINGS. Their concern is technology and textiles. Do you think that we ought to put technology and textiles in the Department of Energy?

Dr. GIBBONS. Well, let me give you a response to that which comes from my own past experience at the Oak Ridge Lab many years ago. This was 20 years ago. Some textile industries were very interested in processing their dye wastes so that they not only would not pollute the streams, but they might be able to recover some of the dyes. They knew of work at Oak Ridge that had to do with chemical separations of liquid systems that had been used to clean up radioactive water that had some radioactivity in it.

Senator HOLLINGS. I can save you time. This is manufacturing technology.

Dr. GIBBONS. Well, just to finish this point, they adapted that to the textile industry at very low incremental cost because the research had already been done, and it cleaned up their problem for them.

In terms of manufacturing technology, I think that is much more of a question and I cannot tell you exactly how, but I would do the following. I would look and see where within the Federal family, whether it be at NIST or NASA's labs or the Air Force labs or the Energy labs, where do we know best about manufacturing technology and could it help. And if so, I would want to try to help facilitate that process.

Normally, you would see that orchestrated through a meeting of the textile industry with the Commerce Department, which is the principal interface there, and then orchestrate the resources that we have in the most coordinated and cost-effective way we can.

Senator HOLLINGS. Do you believe in peer review?

Dr. GIBBONS. In peer review?

Senator HOLLINGS. Yes, of these applications?

Dr. GIBBONS. I strongly believe in peer review, especially of the so-called basic sciences, yes, sir.

Senator HOLLINGS. Well that is what it did. They went to Commerce, could not withstand peer review, so they went out to Energy and got a $200 million contract without any review whatever. Now, you see, your administration is confused as Hogan's goat. I can tell you here and now, all this reinventing government, we had better reinvent a decision. Just tell us.

I can play the game, I have been in it. And I am on this appropriations committee, and we are going to follow where the money is. We are not going to give all that study about dyes and separations and waters. Where the money is, we are going. And if you folks are going to put the money and give that role, it suits me. Give NASA to Energy and jumble it all up.

Defense now has got a line item of $1 billion bucks—never been there before—for the commercialization of domestic technology. So you write Secretary Brown and tell him he has got the role, but you give the money to Defense, you give the money to Energy. So you folks have got to make a decision.

Thank you very much, Mr. Chairman.

Dr. GIBBONS. Senator, I agree with you. I think we do have to follow the money, and I think we all have an important job in front of us to make sure that that is done on the basis of merit.

The CHAIRMAN. Thank you.

Senator Domenici.

STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Senator DOMENICI. Mr. Chairman, I too hope that in due course we can sit down with Senator Hollings and the administration and arrive at something that will be in the best interests of the country. Our only goal is that wherever the best technology and science is, and if we have already invested in it and it is there, that we make it available in the best interests of our competitiveness, whether it be in health.

I might just mention in health one third of the genome mapping program of the country, one of the stellar programs for future health—one third of it is in the Department of Energy right now, and two-thirds in NIH which puts out grants. So I am hopeful that we can meet and talk about this issue at length with our friend.

I have been very understanding of the willingness of the administration or the desire that they move ahead with NIST becoming a bigger player in technology for the private sector, and my friend knows that I have gone along with a very large increase to meet the first year requests of that. I am just hopeful that a better understanding can be arrived at between us all in the next month or so, or perhaps 2 months.

And I say to the administration, I feel very comfortable with what the President has said about our laboratories. If we can follow up with it, I do not think it is going to hurt NIST, I do not think it is going to hurt textiles, I think it will be to the benefit of everyone. And I thank you for your consideration about that in the past.

Maybe I could just ask you a general question and then go on because, as the chairman indicates, we have got to go through a lot of witnesses.

I think that the newest issue around is whether or not the super collider can be managed properly. We will hear more about that, I assume, from the person that allegedly issued an internal document in the Department that says management is very poor. Could you quickly give us your assessment? Can we manage this project under the current structures that we have and are you satisfied on behalf of the President, as his science advisor, that we are doing a good job on that?

Dr. GIBBONS. I think any big project, a very highly complicated project, is inevitably and inescapably going to have problems. That is the very reason for contingency funding. For instance, even a simple construction project has certain contingency funds reflecting the inherent unknowability of the total outcome of an activity.

And I think we see some evidence of some of that happening with respect to SSC. I do believe, for instance, that their contingency funds, as I understand them, are less spent than their project funds at this point. In other words the project, I believe, is about 20 percent along the way and about 20 percent complete, but less than 20 percent of the contingency funds have been tapped. So in a gross sense, that is part of the good news.

I also know that there have been a number of very serious allegations and concerns and internal studies that have been going on, especially over this past month or so. And that, of course, is being led, as it properly should be, within the Department, because the President feels strongly that his cabinet are the people that carry out the work of the administration.

We look forward to hearing the details of the outcome of the study, which I believe has just been completed. We have not had a chance to go over it in any detail with Secretary O'Leary, and therefore I would rather defer to her, if I may, today, in terms of answers to those specific questions.

Senator DOMENICI. I want to thank Dr. Gibbons for what I think was very relevant and positive testimony regarding this project for our people. Thank you very much.

Dr. GIBBONS. Thank you, sir.

The CHAIRMAN. Senator Bumpers.

Senator BUMPERS. Thank you, Mr. Chairman.

Mr. Chairman, first of all I want to make the record crystal clear that my primary opposition to the collider is fiscal. I think the cost is out of control. The figures I gave a moment ago for the—I believe it was 20-year life of the operation of the thing, assuming it is completed at today's projected costs of say $13.2 billion, which I think is highly optimistic.

I want everybody to know that I have no objection to the goals of the collider and in a perfect world would support building the collider. But I think it is a height of fiscal irresponsibility in these days to spend this kind of money. And I also think it is—the second part of the point I want to make is it is certainly the height of irresponsibility to spend this kind of money for research, the results of which are largely not only arcane, but highly indefinite.

As a matter of fact, I think, Dr. Schwitters, you testified essentially that we do not know what we are going to find. We know what we are looking for, but we do not know what we are going to find. Therefore, is it not possible that we are going to find nothing?

Dr. GIBBONS. Senator Bumpers, I am glad I am not Dr. Schwitters, incidentally, as he is in the hot seat today.

Senator BUMPERS. I am sorry, Dr. Gibbons. I will get to him later.

[Laughter.]

Dr. GIBBONS. But I do admire Dr. Schwitters as a colleague and fellow physicist. But not to belittle your point, I think when I mentioned uncertainty I did not mean to imply that the design of this accelerator did not reflect elegantly what we know about the nature of the universe now. We are beginning to see this puzzle come together. In terms of the ultimate structure of matter, it tells us that there are certain kinds of things that would happen, that should be happening in the very specific energy range that this accelerator was designed to operate in.

So we are confident that we will resolve the questions about, for instance, the Higgs-boson. This pushes us into an energy range more than an order of magnitude greater than the Tevatron. It pushes us into a dimension of space and the dimensions of energy that are inherently unknown because we have never been there before, but we are pretty sure we are going to find some things that we know we will resolve some questions. Whether or not the answer comes out positive or negative is a second order thing. If we do not find the Higgs-boson, for instance, that is probably more exciting than if we do find it.

So in physics a negative result is sometimes even more interesting than a positive result. It is in that context that I talked about uncertainty, and I hope I was not confusing.

Senator BUMPERS. Well, you are not here, for example, telling us that we are going to find a cancer cure with this project, are you?

Dr. GIBBONS. I am not going to make claims of what it is going to do with respect to cancer or energy or other things. And I purposely prepared my testimony without any such allegations or speculations.

I would say, however, that it has been the nature of large scientific ventures such as this that unexpected results not only invariably occur, in terms of what you find out in the basic knowledge, but also you have very inventive people being stressed to their limit, in terms of technological capabilities. And that invariably results in the spin-out of ideas and products and services.

I just know in my heart and also from history that that is the case.

Senator BUMPERS. Let me read you something that came to us in a staff memo. The members of this committee got a staff memo that says: The super collider will make some significant contributions in other areas of science, particularly in medical areas. For example, the SSC is developing plans to establish a proton therapy facility at the SSC site for the treatment of cancer.

Now, you heard the chairman. In my opening comments, the chairman responded by saying we make no claims about cancer, and yet we are actually building a cancer facility there; is that correct?

The CHAIRMAN. I did not say we make no claims about cancer. I said that is not a primary purpose of the SSC, but that we did in fact have plans for a proton beam. I mean, it is built in, and it is one of the spinoffs, albeit a small one. We have treated 9,000 patients at Fermi Lab and also in California.

Senator BUMPERS. Well, what is that relevant to? So we have treated 9,000 patients at our radiation facilities. What has that got to do with this?

Dr. GIBBONS. Well, I would venture to say that when you have a facility of extraordinary capabilities, that if at very small incremental cost one can prepare for the potential opportunity to use this in other areas, such as in medical work, if that is the case, then so be it. But I would want to be very careful that the investment on the front end for such site ventures be kept very much contained.

Senator BUMPERS. Are you familiar with Dr. Blumbergen?

Dr. GIBBONS. Nicholas Blumbergen?

Senator BUMPERS. Just a moment.

[Pause.]

Senator BUMPERS. Well, it is going to take longer than a moment. Just a minute.

[Pause.]

Senator BUMPERS. "As an expert in magnetic resonance, I wish to correct a statement to the testimony of the Hon. Henson Moore. I can state categorically that MRI is not a spinoff from SSC-related activities." And then he goes on to say: "This extrapolation of this factually correct statement to the testimony by Mr. Moore that MRI is a spinoff of Fermi Lab and SSC is unwarranted and indeed ill-advised. MRI would be alive and well today if Fermi Lab had never existed."

As a matter of fact, he says the technology is more related to 1911 discoveries than it is to recent discoveries.

Dr. GIBBONS. As you notice in my testimony this morning, I did not relate the MRI to the SSC or particle physics. I talked about MRI as——

Senator BUMPERS. So you would disagree with any of the proponents of this who get up on the Senate floor and say that MRI is a product of this technology?

Dr. GIBBONS. MRI is a product of nuclear physics, Senator. And that was the point I tried to make this morning.

Senator BUMPERS. And not of particle physics?

Dr. GIBBONS. That when people were working in fundamental nuclear physics, they had no anticipation that nuclear magnetic resonance would show up some day as a way to investigate how we look on the inside. It was an unexpected result of fundamental studies about the principles that underlie the way the world works. And it is in that analogous way that I then talk about particle physics and that SSC takes us in an entirely different realm.

Just like these earlier times, I would expect that one would find equally unanticipated results to emerge. But I think you are absolutely right, and the person whom you quote is absolutely right. MRI has nothing to do with SSC except they both come out of physics.

The CHAIRMAN. Would the Senator yield at that point?

Senator BUMPERS. Yes, I would be happy to.

The CHAIRMAN. There are new magnets being designed at SSC which will be used in the MRI. In fact, I have the wires that are being used in a new way to get these big pieces of, I guess it is copper, down to very small wires. It is a manufacturing breakthrough—in fact, it is a major manufacturing breakthrough. These little hairline wires come from a much—this big thing of titanium and copper is squeezed down—you cannot see that—into this hairline, about the size of horsehairs or smaller, in an extrusion process, which is a major breakthrough for the MRI.

Now, it does not come from protons and neutrons and quarks, but it does come from the manufacturing technology.

Dr. GIBBONS. I am glad the chairman clarified the situation. I was speaking about the principles that led to MRI. He is absolutely right that already in the development of SSC and these accelerators, the technology push on the technology of superconducting magnets directly improves the technology of MRI. But I was speaking about the discovery of the process itself.

Senator BUMPERS. On the protons in the treatment of cancer, do you talk about accelerated protons?

Dr. GIBBONS. Yes, in the treatment of cancer, there are a variety of bullets that you go after cancer with. Some of them are chemical, some of them are radiation. Protons and other so-called heavy particles are a way of directing energy in a very precise way into the inside of the body to zap a thing that you want to kill. The protons crash into these cells and molecules and simply break them up, and then the body has to carry them away. It is a way of destroying tissues with very high selectivity.

Senator BUMPERS. Well, it was either Dr. Kromehousen or Dr. Blumbergen who said that we have more than adequate technology

today to use all the acceleration of protons that the human body could ever possibly endure. Do you agree with that?

Dr. GIBBONS. I think so. And, in fact, if my information is correct, I believe out of this multi-billion-dollar effort, the medically-related piece of this planning is about $500,000.

Senator BUMPERS. Well, let me ask you this question. Is it true that there is an SSC component—are we building or are we planning to build a proton therapy facility at the SSC site for the treatment of cancer?

Dr. GIBBONS. Well, I think the people who follow me later this morning and this afternoon could give you more details on that, Senator. But, as I understand it, it is about a half-a-million-dollar planned effort.

Senator BUMPERS. Half a billion, is it not?

Dr. GIBBONS. Half a million, I believe.

Senator BUMPERS. $500,000?

Dr. GIBBONS. I believe that is correct.

Senator BUMPERS. And what is it?

Dr. GIBBONS. It would be a way of tapping the beam so that you could use it in some of these experiments with respect to human tissues.

Senator BUMPERS. Is that the only site in America at which such a facility is going to be built?

Dr. GIBBONS. Not at all. There are treatment capabilities at other accelerators around the country for similar ventures.

Senator BUMPERS. Well, Mass General is spending $30 million for a similar facility. Why are we building one at SSC?

Dr. GIBBONS. I think the Mass General facility is—first of all, I believe it is a cyclotron, if I remember correctly, it is a much lower-energy device and, of course, a much more expensive device than the investment that they are speaking about for the SSC. I am sorry I do not know the particulars that you speak of.

Senator BUMPERS. But my question is: Why would we be building one there? As I understand it, the University of California has one or are building one at the Davis Hospital. Mass General is building one. Why would we build this one?

Dr. GIBBONS. Senator, I would prefer to have the Department of Energy people respond to that.

Senator BUMPERS. Okay. Let me read to you—well, I will skip that.

I have a letter here, Mr. Chairman—strike that.

It is a letter to Science Magazine from Dr. T.H. Gibball, Department of Applied Physics at Stanford. This letter appeared in Science 26 February 1993, and I ask unanimous consent that that letter be inserted in the record.

The CHAIRMAN. Without objection.

[The letter referred to follows:]

SCIENCE, VOL. 259, FEBRUARY 26, 1993

FUNDING THE SSC

The discussion during 1992 about whether or not to continue funding the Superconducting Super Collider (SSC) was hardly an example of scientific clarity and accuracy. At least five arguments that were made for proceeding with the SSC deserve more careful scrutiny.

First, the argument was made that it is necessary for the United States to fund the SSC for the sake of national pride. This attitude now seems quaintly anachronistic. In 1992 both Corning and AT&T signed agreements with groups in Russia to carry out collaborative research in optoelectronics, while IBM, Toshiba, and Siemens signed an agreement to mutually develop the next generation of silicon memory chips. These high-technology fields are more relevant to national competitiveness than owning the highest energy accelerator. These corporations have faced the reality of a global economy and have realized that products requiring billion-dollar research investments can no longer be created alone, just for the sake of corporate or national pride. Perhaps it is time for the high-energy research community in the United States to join a global research community in the work that will be possible on CERN's (the European Organization for Nuclear Research's) new accelerator. Once the limits of that machine are exhausted, the community could then more sensibly argue for another that would represent an advance in global rather than national capability.

Second, arguments were made to imply that the high-energy experiments of the SSC are uniquely important. The SSC is indeed a worthy experiment that should be justified on the basis of its scientific merit because extending the frontiers of knowledge is a worthy challenge. However, this challenge is real for all fields of science and is not exclusive to high-energy physics. It is not possible to judge the intrinsic worthiness of important experiments in different fields of science. It is fruitless, for example, to compare the importance of finding out more about the origin of the universe with that of finding out more about the origin of life. The most important experiments in particle physics deserve support because they are likely to provide new understanding of the structure of the universe, but they are not necessarily the most important experiments in physics, chemistry, or biology.

Third, it has been said that, "[i]n the SSC we will gain experience with the first large-scale use of superconductivity. The SSC will transform superconductivity from a craft to an industrial capability". The requirement for a large number of superconducting magnets for the SSC will be an anomalous market demand of relatively short duration. The superconducting industry has been built around today's products, such as magnets for magnetic resonance imaging (MRI) machines. In 1992, approximately 1100 such MRI systems were sold, each containing 20 to 40 miles of superconducting wire and representing a total revenue of $1.6 to $1.8 billion. The scientific discoveries that made such magnets possible were made during benchtop experiments in 1911 and the late 1950s and early 1960s.

The applications that will result from the SSC, quoted by Watkins—maglev trains, ship propulsion, energy storage magnets, power transmission cables, motors, and generators—could be built quite adequately with today's technology. Some were built as prototypes a decade ago. The lack of widespread use of such products is not a result of unavailable technology but of inadequate market demand. The SSC will not suddenly create such a civilian market demand. The SSC will do nothing to enhance the nation's capability to make use of the new superconducting materials that were discovered in 1986. These would allow commercial systems to operate at higher temperatures (possibly cooled with liquid nitrogen rather than helium), which is a factor that would likely change their acceptance in the marketplace.

Fourth, the impression has been created that support from the scientific community for the SSC was "overwhelming." Despite the roughly 2000 signatures collected in support of the SSC, there was strong opposition to it across some parts of that community, particularly among the condensed matter scientists who make up the largest division of the American Physical Society.

Fifth, the impact of SSC expenditures (about $10 billion to construct and $1 billion a year for interest and operation) on other high-energy experiments and on other fields of science should have been more carefully evaluated. The budget in the United States for the operation of high energy experiments is about $630 million a year. Even allowing for the possibility of a 50% increase in funding for high-energy physics over the next decade, operation of the SSC would seem to consume all of the extrapolated annual budgets for high-energy research at universities ($100 million), Brookhaven National Laboratory ($90 million), Fermilab ($225 million), and the Stanford Linear Accelerator Center ($140 million). The net economic effect of funding the SSC is quite likely to be negative, in that money might be reduced in fields other than high-energy physics that have more consistently produced new and valuable spin-off technologies.

T.H. GEBALLE,
Stanford University.
J.M. ROWELL,
Conductus, Inc., Sunnyvale, CA.

Senator BUMPERS. Dr. Gibbons, do you know Mr. Cipriano at the Energy Department?

Dr. GIBBONS. I have met Mr. Cipriano. I do not know him personally in any detailed way, and I have not seen him for many, many months.

Senator BUMPERS. Have you seen his famous memo?

Dr. GIBBONS. I understand there was a memo in his PC that had to do with his concern about the management issues at the SSC, but I am not familiar with it and I have not seen it.

Senator BUMPERS. Here are his recommendations:

No. 1, take a year to restructure and fix the problems before going on.

No. 2, existing contracts should be honored, but no new starts.

No. 3, reduced budget in 1994.

No. 4, options developed for execution in 1995 be in a strong position for 1995 funding.

No. 5, it is recommended that the President's budget request for 1994 for the collider be reduced to $400 million.

Do you disagree with that?

Dr. GIBBONS. Well, it sounds like a thoughtful exploration of one set of options, and I am sure there are many that the Department has explored. I could offer the following responses, not having had a chance to think about it that much.

First of all, I think to take a year to fix things—I would need more information, because if you simply bring to a halt a major operation, you have a fixed cost running that has to be taken into account. But sometimes it does pay to pause or at least to slow down and go a little bit more carefully and deliberately about things. The administration chose this option in terms of our stretch-out philosophy in order to enable more time for an internationalization of the effort, and also to lower the annual costs during these critical next several years.

I think, though, that we should think about Mr. Cipriano's option along with other options that I am sure Secretary O'Leary has had to undertake to examine and simply see how they stack up in a comparative way.

Senator BUMPERS. He has recommended action: Immediately fire the super collider lab director. I assume he is referring to Dr. Schwitters?

Dr. GIBBONS. I would like to know on what basis if I were to answer that question.

Senator BUMPERS. Well, I will come to that in just a moment.

His other two recommendations are: Meet with Senator Johnston to discuss the Department's position; work with Senator Johnston to develop a Senate game plan.

Now, Senator Johnston does not need the Department of Energy to develop a game plan. He always has his own game plan.

[Laughter.]

Senator BUMPERS. And you are seeing an integral part of it this morning.

[Laughter.]

The CHAIRMAN. You are not part of it, Dale.

[Laughter.]

Senator BUMPERS. I asked for an evenhanded hearing this morning, and you know what I got.

[Laughter.]

Senator BUMPERS. This memo goes on to say that replacing the Lab director now would allow a new director to come on board before the Senate vote in September, and effectively campaign for continuation of a restructured program that he is committed to make work. It will also allow discussion with URA, that is University Research Association, about contract restructuring to go on without uncertainty about the Lab director's tenure.

A further and perhaps more compelling reason for replacing the Lab director now is that it may be the only way to keep the Lab from falling apart before the Senate votes.

Just a moment.

Morale is very low. Confidence in existing management is practically nonexistent, and cost and schedule trends are worsening at an alarming rate.

Do you want to comment on that?

Dr. GIBBONS. Well, it does sound like Mr. Cipriano is concerned about the matter. I do not know whether he was writing that memo to himself or what, but it does sound like he was exploring the whole series of legitimate questions about where should we go from here.

How truthful are the allegations?

At least from what you have read, he seems to be satisfied that these are very serious. I know that he is concerned about morale.

You know, it strikes me that when you have projects that are a decade long, involve a number of nations and are very complex, and go on 12-month funding intervals that alone can very seriously affect morale. But I worry about the fact that Mr. Cipriano apparently feels that, as in early Jewish times, when we have a problem, we find a scapegoat and throw him down the hill. And I am not sure that is the most sensible action to take in this situation.

Senator BUMPERS. Dr. Gibbons, he is—I do not know Joseph Cipriano. I know that he is the associate director of the Department of Energy's Research Office. So, I assume he did not just fall off a turnip truck; that this was written in good faith.

Dr. GIBBONS. I am sure that is the case, Senator. Also, I am not sure how much large project management Mr. Cipriano has done before in his life. I just do not know.

Senator BUMPERS. Well, let me ask you this. As a Senator from Arkansas, who occasionally disagrees with his President, do you think I am serving my constituents well for funding this thing in light of memos like this from the Department of Energy, which has the ultimate responsibility for it?

Dr. GIBBONS. Senator, I think you serve your constituents well in raising these serious questions and seeking accurate and complete answers to them. And I would hope that at the end of the day, when all of the people that follow me come forward, that the debate will be sufficiently illuminated or elevated that you will be in an even better position to be able to make your decision.

The CHAIRMAN. Senator Bumpers, I do not want to cut you off.

Senator BUMPERS. Mr. Chairman, no, I know you do not.

[Laughter.]

The CHAIRMAN. We do have three other witnesses.

I would like to put into the record, since we referred to Mr. Cipriano's so-called memo, which is an unsigned memo, along with a letter, the original of which I do not have, but it is signed by the nine associate directors saying that they want to put on record our reactions to allegations that morale at the SSC Laboratory is low because of a lack of confidence in management attributable to our director, Dr. Roy Schwitters. The assertion is flatly incorrect. And it goes on to talk about technical progress.

[The material referred to follows:]

ISSUE

Our beloved contractor, University Research Associates, and their industry associates have been lobbying the White House, Congress, and Texas on their solution to SSC management concerns and project congressional strategy. Their solution entails retaining the existing Lab director and keeping the team together. It is reported that Senator Johnston at least is supportive of URA's proposal. The State of Texas has thus far stayed neutral and it is believed they will support DOE's position. It is imperative that the Department retain leadership in this initiative. URA's behavior, uncoordinated with the Department, is further evidence of their unwillingness to cooperate with the Department on the SSC program.

Recommended Department Position

- Take a year to restructure and fix problems before going on
- Existing contracts honored - No new starts
- Reduced budget in FY94
- Options developed for execution in FY95
- Be in strong position for FY95 funding

It is recommended that the President's budget request for SSC in FY94 be reduced to $400M. This will allow all contracts currently in process to continue but will not support any new construction starts. In addition to continuing existing construction, and avoidance of termination costs of $400-$600M, this funding level would support implementation of the new program management approach, development of a well thought out termination plan that could be implemented in FY95 if desired, and development of reduced scope or phased implementation alternatives for SSC.

If this approach is selected, we must be able to lay out for the Senate viable phased implementation options to be studied. These are being developed now and must be validated for scientific merit. The advantage to a phased approach rather that just joining CERN is that CERN can never reach the energy regions planned for SSC but a phased SSC could at some future date.

Recommended Actions

- Immediately fire SSC Lab Director
- Meet with Senator Johnston to discuss Department position
- Work with Senator Johnston to develop a Senate game plan.

It is important that the Department get its position in front of the White House and Congress as soon as possible. It is recommended that the Secretary immediately terminate the Lab Director as the first step in the resolution of management issues. This is necessary anyway and recent behavior does not allow a graceful change. Replacing the Lab Director now would allow a new Director to come on board before the Senate vote in September and effectively campaign for continuation of a restructured program that he is committed to make work. It will also allow discussion with URA about contract restructuring to go on without uncertainty about Lab Director's tenure. A further and perhaps more compelling reason for replacing the Lab Director now is that it may be the only way to keep the Lab from falling apart before the Senate vote. Morale is very low, confidence in existing management is practically non-existent and cost and schedule trends are worsening at an alarming rate. A new leader is needed now.

Superconducting
Super Collider

2550 Beckleymeade Avenue
Dallas, TX 75237-3997
214 708 9000

August 3, 1993

Dr. John H. Marburger
Chairman of the URA Board of Trustees
President
State University of New York
Stony Brook, NY 11794-0701

VIA FAX: 516-632-6252

Dear Dr. Marburger:

We, the undersigned Associate Directors of the Superconducting Super Collider, want to put on record our reactions to allegations that morale at the SSC Laboratory is low because of a lack of confidence in management attributable to our Director, Dr. Roy Schwitters. The assertion is flatly incorrect. In fact, under Dr. Schwitters' leadership the Laboratory has continued to make remarkable technical progress despite the substantial handicaps of funding shortfalls and votes in the U.S. House of Representatives this year and last to terminate the project. Under these circumstances, it is no surprise that the workers at the SSC have a difficult time keeping their spirits up and their morale high, but Dr. Schwitters has been a positive, not a negative, influence.

Sincerely,

Dr. Richard Briggs

Dr. John Rees

Dr. Gerald Dugan

Mr. George Robertson

Dr. Frederick Gilman

Mr. Edward Siskin

Mr. Jon Ives

Mr. E. Jack Story

Dr. Raphael Kasper

Dr. Thomas O. Bush

Dr. Theodore A. Kozman

The CHAIRMAN. I am sure there are some who do not agree with the associate directors and some who say that morale is low because of the Senate and because of Senator Bumpers, but at least those associate directors believe that morale is not low. And I would like to put that in the record, as well.

Senator Craig.

Senator CRAIG. Thank you very much, Mr. Chairman.

I do want the record to show that Senator Bumpers is my friend. All right.

The CHAIRMAN. In spite of everything.

[Laughter.]

Senator BUMPERS. With those kind of caveats, I know what is coming.

[Laughter.]

Senator BUMPERS. I was a trial lawyer, and every time the judge, at the conclusion of the trial, said, "Mr. Bumpers, you have done a superb job of representing your client," I knew what the verdict was going to be.

[Laughter.]

Senator CRAIG. Mr. Chairman, Dr. Gibbons, let me thank you for your testimony. I will be short. I do appreciate the time, and I do want to listen to the rest of the panels with great interest.

I had mentioned in my opening comments the question of priority, and it is this Congress' responsibility to establish policy that drives priority. Last night, we heard from a President who was attempting to establish some priorities. And what I am suggesting at this moment is not in any way reflective on his decisionmaking. But in his comments about a budget last night was a sum of money that will not be talked about too much here: for $214 million to pay for out-of-work people in the Pacific Northwest because of a decision driven by a public policy in this country known as the Endangered Species Act, and that money dealing with the spotted owl.

I have drawn a simple conclusion: That is bad political science that has driven that. It has hurt an awful lot of people and it has put them out of work, and that is a bad priority. And yet, we are still spending money there.

Now, it is not $13 billion. But, in the end, it will be several billions of dollars of a misplaced and mislocated economy and people badly damaged. That is bad public policy in my opinion and, therefore, a bad expenditure. And it is a result of bad political science and, ultimately, bad science, in my opinion.

I cannot prejudge this one, but I can at least suggest that we ought to push the envelope of science, keep as much politics out of it as we can. I have always thought that when you try to commingle politics and hard science you create great problems, usually very expensive problems.

I would hope, Mr. Chairman and Dr. Gibbons, that whatever we do in this, we divide it and separate it very carefully, and that we allow the scientists and the engineers, and hopefully not too many of the politicians to commingle here and result in a politically-designed Superconducting Super Collider, instead of a scientifically-, engineeringly-, if you will, designed one.

I would guess that the money we will spend on the super collider in this budget will be much better spent than that one priority I mentioned of the $214 million for the spotted owl issue.

Dr. GIBBONS. Senator, if I might respond briefly to that, those problems that you raised about the Northwest and the SSC and the space station and others are not issues that are new to the Congress. They are not new to this administration. We have inherited all of these from actions of prior Congresses and prior administrations.

I would say that with respect to the *Northwest* decision, that was also a typical one. It is one that attempts to resolve a problem that has been festering for decades, especially for the last 10 or 15 years. And the decision is not just over the spotted owl but the interaction between species that are endangered such as the owl and others, endangered by human activities in cutting old forests, which in turn are silting streams, which in turn are wiping out salmon, which in turn are putting fishermen out of work off the Northwest coast, which in turn relate to the hydroelectric power systems up there and how they affect the fish.

So, what we are trying to deal with is the evidence of a very complex ecosystem that in a sense we have been screwing up. And the question is how do we resolve it so we have a sustainable system in the Northwest for an economy, for an environment, and do it at minimum cost. And we are inheriting a lot of problems.

So I cannot say that it is just an argument over the owl. The owl is simply a favorite sort of emblem of a much more complicated issue.

Senator CRAIG. Well, we will not debate that. You are right. The owl is surrogate to a broader issue, and I would hope that SSC answers a variety of those questions strangely enough in the area of the environment. I think any day that you would spend during rush hour traffic in downtown Los Angeles might suggest that many decades from now, through the use of the science that might be spawned by SSC, we would see a cleaner environment because we had chosen or would be able to choose a different energy source to propel man or woman along the streets of Los Angeles or any other metro area. And the result of doing it would be a much better environment. That is part of the goal here.

My only argument with the spotted owl and the salmon and all of that is that we do have forest practices now in place that do not result in the siltation of streams, but we do not have a political mind set that suggests that the only way you save the world is stop logging, and that is a different kind of argument that we do not want to get into today.

But what I am saying to Senator Bumpers is that there is a unique linkage. Part of what drives us in these kinds of sciences is a better world, and the spinoff of the better world in the area of physics and superconductivity might be a much cleaner Los Angeles or Chicago or anywhere else for that matter because our science took us to a better source of energy that caused that environment to change. That is all part of the equation.

Dr. GIBBONS. That is very well said.

Senator CRAIG. And it is not politics that gets us there, it is science. The trouble with the spotted owl is that it is too much politics and not enough science. Thank you very much.

Dr. GIBBONS. Thank you, sir.

The CHAIRMAN. Senator Bennett.

Senator BENNETT. Thank you, Mr. Chairman. I have no questions. I wish I had had you as my professor of physics when I was in college, and then I would probably be smart enough to ask questions.

Dr. GIBBONS. Thank you, sir.

The CHAIRMAN. Thank you.

Senator Specter.

Senator SPECTER. Thank you, Mr. Chairman. I wish that I had had a professor of physics in college.

I arrived late, and you may have discussed this to some extent, but I would be interested to know what the practical applications are that we will see in medicine and other fields. We are making a tremendous investment. I supported the super collider last year, and I would like to support it this year. But the question really is balancing against the tremendous number of other needs which we have with the deficit.

I would be interested to hear an expansion, if you would, of what the practical effects will be. How will we benefit the United States in collateral ways if we make this very substantial investment?

Dr. GIBBONS. Senator, I did try to address this before you arrived in the room, but I will try to repeat what I think are the essential points I tried to make.

Senator SPECTER. Thank you.

Dr. GIBBONS. First of all, I spoke to the validity of the science itself. This is the premier flagship instrument to move ahead in a very exciting era and time of interest possibly culminating, although I hesitate to use that word, a millennia-long search to understand really what we are made of and where we come from. So, in terms of value it speaks directly to a thing that has not so much dominated but pervaded human thought since before history began. Who are we? Where do we come from? What makes the world work? Out of that comes basic knowledge.

And basic knowledge, I think as we all accept, has its own value without any other measure. At the same time we know from times past that basic knowledge has led us to all of the extraordinary things that now manifest themselves in goods and services derived from technology.

I will not predict to you that this is going to help cure cancer because I think that is not its primary purpose. I will say that we will learn a lot more about how things work, and that in essentially every past experience this has resulted in things that have meant direct impact on our lives. So, the technological value of this, as well as its scientific value, I think is not questionable.

The question before you today is, and I fully appreciate your concern, is this the best way we can spend our money? Is there some alternative that promises more for our future? That is a very difficult one to answer, and I will not propose to do it this morning.

I would only say this, that in terms of the frontier of physics, in terms of the things that challenge and excite and grab the

attention and imagination of our brightest young scientists, many of them, this is the sort of challenge that will bring them forward, will develop them into mature minds that will contribute not only in physics but in other ways. It has the excitement to draw not only creative people but, therefore, to precipitate creative ideas, and those will show up in a variety of ways in technology. And I am not going to tell you what kinds of technology except it probably is related to such things as the use of very high magnetic fields for transportation, as a prior Senator mentioned, and other things that we cannot really anticipate at this point, but we know from history that it happens.

And finally, in terms of social value, I think this manifestation of our commitment to push the frontiers of human knowledge, to continue to lead the world in key areas of science has its own value, and it reflects a fascination that we all as humans have always had to try to understand how things work.

Senator SPECTER. Dr. Gibbons, I have a special interest in the MRI, having been the beneficiary of one recently. I see in the briefing papers that this is going to have some impact on magnetic resonance imaging, MRI, which is certainly a marvelous device. And I would be interested to hear how the superconductor will have an effect on that. How does that work?

Dr. GIBBONS. I brought out earlier that those people who first investigated atomic structure and nuclear structure were making these investigations simply because they were led by their curiosity about how things work. And a totally unanticipated outcome of some work in solid state nuclear physics called nuclear magnetic resonance led directly to MRI as an unanticipated outcome of basic research.

I do not expect MRI to be relatable to SSC except that the SSC pushes the envelope of technology related to a very fundamental part of MRI, namely very high magnetic fields for the so-called high magnetic field resonance phenomenon. So, it is an associated technology. It goes along in a parallel path with the kinds of technologies that will inevitably improve the capabilities of MRI and other type imaging devices.

Senator SPECTER. Dr. Gibbons, when you say that we will have some insights, as you put it, in what we are made of and where we came from, are you suggesting that this is going to give some basic knowledge to the origin of man?

Dr. GIBBONS. It will give basic knowledge to the origin of the very material we are made of. In my earlier career I investigated, using nuclear physics, the origin of the heavy elements of the solar system. And I found out that all of us, you and I and all the rest here as well as all the material in this room, is literally star dust. And it was a very interesting exploration of the earliest origins of matter, that is of the heavy elements.

What we are studying with SSC is how that matter itself came to be, what is the ultimate basis or building block of that matter, and at the same time what really happened with the Big Bang? How can we understand the universe as we observe it today with our telescopes? And one of the best ways to answer that question of why we see those funny things out there is looking not outward

but inward, at the smallest particles we can find, at these same fundamental building blocks.

So, I mentioned that the SSC simultaneously looks inward to the smallest constituents of the universe to answer questions also about the largest parts of the universe, namely cosmology. So, it integrates the largest with the smallest.

Senator SPECTER. The last question I have, Dr. Gibbons, relates to the use of magnets, and involves a key constituent of mine, Westinghouse. And I would be interested to know what you see as the projection of further research on magnets, and how that will evolve as the program moves forward.

Dr. GIBBONS. Well, the SSC uses superconducting magnets in a quantity that almost boggles the mind. For instance, it requires very large complicated precision magnets being produced by the thousands in order to keep this beam of countercirculating protons in very tight formation, going around a 54 mile circuit. And so this is pushing the state of the art of technology of constructing superconducting magnets and getting their costs down.

As costs come down, other applications then become cost effective. And I think that is what one will see, the break in the cost curve which in turn will open opportunities for other uses of very high magnetic fields.

Senator SPECTER. Thank you very much, Dr. Gibbons. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you. Dr. Gibbons, thank you very much. You have been very helpful to the committee.

Next we have a panel with Dr. Steven Weinberg, Professor Philip Anderson, and Mr. Robert Galvin. Let me say, gentlemen, that a vote is expected shortly. So, when the gong sounds I will run over and vote, and come back as quickly as I can.

As I mentioned earlier, our first witness is Professor Steven Weinberg from the University of Texas, and a Nobel laureate in the field of high energy physics. Professor Weinberg, please proceed.

STATEMENT OF DR. STEVEN WEINBERG, THEORY GROUP, DEPARTMENT OF PHYSICS, UNIVERSITY OF TEXAS, AUSTIN TX

Dr. WEINBERG. Thank you very much. I am grateful to the chairman of the committee to allow me to come here to talk about the super collider. Actually, Dr. Gibbons has done such a great job of describing the science to be done at the super collider that I wish I could turn the tables on him and describe to you what is going on in the White House.

[Laughter.]

Dr. WEINBERG. But since I do not know anything about that I have to stick to my own profession, which is science, and try to tell you a little bit more about the science of the super collider.

In essence, the super collider is a machine for creating new kinds of matter, particles that have existed since the universe was about a trillionth of a second old, but which are present in our theories and which we know can be produced. We need energy to produce these particles. These are very heavy particles. We learned from Einstein that the more mass a particle has the more energy you need to produce it, and these particles require an energy about 20 times higher than the energy of the largest accelerators that now

exist, which is why the super collider is so big, and therefore why it is so expensive.

This little statement that I have made really does not do justice, however, to what the super collider is about because particles in themselves are not really that interesting, at least not in the way that people are interesting. If you have seen one proton you have seen them all. We are not really after the particles, we are after the principles. The particles are a means to an end. The end is of understanding the principles that govern matter and energy and force, and everything in the universe.

We have made a great deal of progress in that direction. Culminating around the mid-1970's, we developed a theory called the standard model which encompasses all of the forces we know about, all the different kinds of matter that we can observe with existing laboratories.

The standard model is not the end of the road. It is obviously incomplete. It has a lot of unexplained features, and a lot of things you just have to put in by hand because that is the way you measure something, so you put in that value, and it leaves out things that are pretty important, like the force of gravity. So we know it is not the last word.

We have made essentially no progress since the mid-1970's in going beyond the standard model, and we know why. The reason is because we have got about as much as we can—not quite all, but we have got about as much as we can from the existing facilities. We have to go up to a higher level of energy.

What energy? Well, as a matter of fact the standard model tells us because it itself tells us the nature of its own incompleteness. The particles that we know, quarks, electrons and so on, they all have mass. Something happened when the universe was very young, and in particular when the universe was about trillionth of a second old, after the Big Bang—a kind of a freezing. Before that, the electrons and the quarks which were present in very large numbers had no mass. After that moment, they had.

At that moment, forces came into play. We know they have to exist because we can see electrons and quarks have mass, but we do not know exactly what they are. This is the question that the super collider is specifically designed to answer.

The standard model tells us that these new particles and forces must be found at an energy not greater than 20 times the energy of existing accelerators, and that is why the super collider was designed to have the energy it does. It is not just that perhaps we enjoy a demolition derby of slamming particles into each other at higher and higher energies. We are doing it for a purpose and we have a definite goal in mind.

Senator Bumpers asked, is it not possible that we will not find anything new. And although he is not here, I would like to answer. No, it is not possible that will not find anything new. We can actually prove mathematically that new forces and particles must show up at these energies. What we cannot say without doing experiments, because physics is an experimental science, is precisely what they will be. It may be the Higgs boson that Dr. Gibbons mentioned. It may be other particles called technicolor

particles. But we know with certainty that one or the other of these alternatives must show up.

This is really quite unusual. In the past when we have come before Congress to ask for funds for new accelerators, generally speaking the argument has been that if you increase the energy it is like opening up a new window on the universe. You are bound to find something exciting and new. And that has always happened, or virtually always happened in the past.

This time, unusually, we are in a different position. This time we can say whatever other exciting new things may be discovered there is something that we know will be discovered—the solution to the problem of what happened when the universe was a trillionth of a second old to give the particles the masses they do have.

Most of these new kinds of matter that would be produced at the super collider are highly unstable, which is why they are not around now and have not existed since that early time. There is one possible exception, which is of particular interest to astronomers. There is a kind of particle which exists in some of ~~our~~ theories, the most promising theories, which is usually called a neutralino. The name means electrically neutral. It would be heavy and stable. If it has those properties, it would have survived the Big Bang in very large numbers, and we have hints from astronomy that that is true.

Astronomers tell us, at least most of them seem to think, that most of the matter of the universe is not in the form of ordinary atoms. It is dark matter in between the galaxies, and it does not consist of ordinary protons, neutrons, and electrons. It is something exotic and new, and that exotic new particle might very well be discovered with the super collider.

The super collider may settle the question of what most of mass of the universe consists of, with the protons and neutrons and electrons of which you and I are composed just a small contamination, but we do not know that that is going to happen. That is an example of the kind of result that we cannot predict. But there is this other one about the origin of mass that we can predict.

Now, some of us think, although it is not a universal view among scientists, that if we keep going in this way we are going to eventually come to a final theory. We are going to come to a simple set of principles which will be almost self-evident and that will be at the bottom of everything, that will be completely universal and govern everything in the universe. We do not know that that final theory really exists. We hope it does. I think it does. We certainly do not promise that the super collider will reveal the final theory.

What we do know is that we are not making any progress now. That I can tell you with absolute certainty. And the super collider is designed to get us moving again, and it is the only way that we know that we are going to get moving again.

This is really the outer frontier of science. Science goes on forever. The discovery of the final theory is not going to end science. It goes on. There are fascinating questions in physics also which will survive the discovery of a final theory, which will not be answered by it. Questions about at how high a temperature

superconductivity works, or questions of how does the mind work and how do we remember things. None of these questions are going to be answered by the kind of theory particle physicists are working toward.

But there is a sense, nevertheless, which is that this kind of elementary particle physics is at the most fundamental level of science. That is, if you ask any question, for example how does superconductivity work, you get an answer. You get an answer in terms of the properties of electrons and electromagnetic fields and other things. And then you ask, well, why are those things true? And you get an answer. You get an answer in terms of what we now call the standard model. We had that in the mid-1970's.

And then you say, well, why is that true? You do not get an answer. We do not know. We are at the frontier. We have pushed the chain of questions why as far as we can, and as far as we can tell we cannot make any progress without the super collider.

Well, who cares? You know, there are a lot of people, a lot of Americans, a lot of members of Congress who really see science only in terms of its applications. And that is a respectable view. Not everyone is turned on by the same things. Not everyone likes classical music. Not everyone has this hunger to know why the world is the way it is, and we have to live with that. I find it sad, myself, but that is the way people are.

It is true that scientists like myself, many of the best scientists throughout history, have not done their work because they had applications in mind. But there has been a bargain. Deborah Shapley had a piece in the op-ed page of the Washington Post this morning which said pretty much the same thing. She called it a compact between science and society.

We do our work because we are looking for things that are fundamental, that are universal, that are beautiful, and I am not referring only to particle physicists here. This applies equally to condensed matter physicists, to biologists, to astronomers. We do our work because we have something purely scientific as our goal.

Society often does not care that much about that, but wants applications. It wants new medicines, new technology, sometimes it wants new weapons. Nevertheless, it supports pure science. And in this country in particular it has supported pure science in the post-World War II period well, even when it has become expensive, as high energy physics and space astronomy has become expensive, and as other branches of science like the genome project are increasingly becoming expensive.

And the bargain has worked. The scientific work which we do in order to satisfy our urging to understand the universe provides what society wants. It provides the medicines and the technology, and even the weapons.

When the theoretical physicists who developed quantum mechanics developed quantum mechanics because they were grappling with nature at its outer frontiers. They wanted to understand why atoms behave the way they did. That was then the question that confronted them. They had no idea that quantum mechanics would become the basis of our understanding of matter, superconductors, semiconductors, metals, and in fact a large part

of the world's industry is now based on our understanding of quantum mechanics.

And likewise, experimental physicists in the 1930's who developed accelerators, the early cyclotrons of Ernest Lawrence were not developed because anyone was thinking of radio isotopes for medicine or nuclear weapons that would win World War II.

The reason I think that this bargain works, even though the two sides have different aims, is that the search for knowledge at the frontier pushes us to a kind of technological and intellectual athleticism. It is when you address the deepest questions that you are most pushed to develop new technology as, for example, new magnets, new methods of parallel computing which are going into the super collider. And also it is when you move into a new country that you discover wonderful new things as Columbus did. He did not have the idea of discovering the potato. But it is when you enter a new continent that you discover new things which have uses that you cannot imagine. And that is the bargain we want to keep with society, we scientists, and now the bargain seems to be unraveling.

The opposition to the super collider seems to me, much of it, to represent a real lack of faith in the future of support of basic science. And I am really worried that the issue here goes beyond the super collider, it goes beyond high energy physics, and has to do with society's support with basic science. I am very worried about that.

Now, in preparing my testimony I took a look at testimony I gave before a Senate committee in 1987, and I have to say that although I am now from Texas in 1987 the site had not yet been chosen to be Texas. And I have been supporting this all along. I am not here as a representative of Texas.

I read over my testimony and I was really struck by the fact that very little has changed. Back then, in 1987, I said we were stuck and we had made no progress beyond the standard model because we were starved for new data. And we are still stuck. That has not changed.

We have not discovered any technological obstacles, so the technology is still in the same state except now we know we can build the magnets. Then we just thought we could. Now we can see we can do it.

One thing that has changed, of course, is the super collider project exists. It is there. We have I do not know how many miles of tunnel, it changes every day, and we have spent some $2 billion and spent 10,000 man years of work. But seeing that the project is the same project that we decided on in the late 1980's and that there is no change in the scientific motivation, there is no change in technology except positive ones, why are we arguing about this? What is going on? Why is this such a hot topic? Why are some Senators and Congressmen devoting a large part of their waking lives to fighting the super collider?

Well, some critics of the super collider point to mismanagement and inflated costs, and I am not the best one to talk about that. I am not part of the super collider management. My only connection with the super collider is as an unpaid advisor, and I

am not an expert in management anyway, and people you will hear this afternoon have a lot more to say about that.

But hearing about all these accusations of mismanagement and runaway costs, I did, to the extent that I am able, look into this. And I would like to go on record here, on the basis of what I have been able to read and find out, that in my opinion there has been no mismanagement of the super collider. That is an exceptionally well managed program. And I would be glad to answer questions as well as I can about that. I wish Senator Bumpers was here because I would like to be attacked on that issue.

Also, I do not think that there have been cost overruns. You hear figures going up from $4 billion to $13 billion. I regard these figures as either mistaken or dishonest. The first time that there was a serious estimate of the total project cost was in the late 1980's, I believe 1989. And the total project cost was—no, excuse me, it was earlier. It was estimated as $5.9 billion, and then it did go up to $8.249 billion, partly as a result of a stretch out of the project from 8 to 10 years, and partly because of technological developments.

That, as far as I know, is the only cost increase. If you fully funded the accelerator at the level, with the spending profile that was originally anticipated, it could be built today for $8.249 billion. All other increases have to do with stretching out the project. And if you stretch out the project it can cost anything you like, of course. You can make it cost $100 billion if you like, if you let it go until the 23rd century.

But leaving aside stretch outs, which are not in the control of the management or the scientific community, there was a modest increase in cost from $5.9 to $8.2 billion, and even that was partly due to stretch outs. And all other figures are just so much fiction.

Well, I heard a bell. Perhaps I should terminate my testimony.

The CHAIRMAN. You have time. Take as much time as you like.

Dr. WEINBERG. Well, let me just say—I am pretty nearly at the end. Any project should of course be terminated if there is a change in the technology. We terminated the Isabelle Project, which was the forerunner of the super collider, because the scientific community decided that changes in physics goals and in magnet technology made that not the right project. Nothing like that has happened with the super collider.

It is sometimes argued that, well, we have got to stop the super collider because the country is in trouble financially. Senator Hollings said we cannot afford it. I am glad Senator Hollings also said we cannot afford to keep the lights on in this building or to pay his salary because I think that puts that remark in perspective, because we are keeping the lights on this building and as far as I know we are continuing to pay his salary.

We can say we cannot afford anything we are doing, but in fact we are going to go on doing a great many different things, and we have to decide which things are worth doing and which things are not worth doing.

The super collider is six tenths of a percent of our research and development budget. As a method of cutting the deficit it has a purely symbolic value, and I am afraid that is what has happened. The super collider has become a symbol of Congressmens' and

Senators' desire to cut the deficit. Cutting it really has nothing to do with reducing the deficit. It is a drop in the bucket.

I think that this argument that we are in bad times financially, we have got a runaway deficit, we have got to cut things like this, is very disturbing for another reason. The super collider was started in relatively more prosperous times. It was clear from the beginning it would be a 10-year project. Now we have worse times. We are more worried about the deficit. We want to stop it. We have already spent $2 billion, 10,000 man-years of work. Throw it away.

Well, when are we going to start it again? When are we going to start doing basic science again? We are going to start it again at some future time when the economy is good again. And then if we start a project that takes 10 years and the economy turns bad during those 10 years, as it inevitably will, we are going to stop it again. I do not think that is realistic. That is not the way to run a responsible science program. It is not the way to run a responsible government.

It seems to me that one should be honest about this. If the super collider is killed this year, it is killed for good. And what is killed with it is high energy physics in America. And that may be the beginning of the killing of support for basic science in this country.

This is a decision that should not be taken on the basis of the politics and the economics of 1993. You are looking at a decision which is going to affect the future of science in this country and the future of the country for many decades to come.

Thank you.

[The prepared statement of Dr. Weinberg follows:]

PREPARED STATEMENT OF DR. STEVEN WEINBERG, THEORY GROUP, DEPARTMENT OF PHYSICS, UNIVERSITY OF TEXAS, AUSTIN, TX

Mr. Chairman and members of the Committee: I am grateful to you for giving me this chance to present my views about the scientific value of the Superconducting Super Collider program.

The super collider will provide benefits of various different kinds. There are spinoffs from the demanding technologies involved in building the accelerator and detectors—high speed on-line computing, large scale cryogenics, high field superconducting magnets, and so on. Some of these will be described here by Mr. Galvin. The super collider and its contractors provide high tech jobs throughout the U. S., that can take,up some of the slack left by cutbacks in defense industries. The super collider will help us to keep a cadre of gifted scientists in this country. The super collider will be a stimulus to science education. These are all valid and important reasons for building the super collider, but I want to talk here about one other reason, one that underlies all the others: it will allow us to make great scientific discoveries.

To put it very briefly, the super collider is a machine for creating new types of matter—elementary particles of types that were abundant during the first trillionth of a second of the history of the universe, but not since then. These particles are too heavy to be created in any existing accelerator; Einstein taught us that the heavier the particle, the more energy we need to create it, which is why we need the 20 trillion volt energy of the super collider beams.

But this brief statement doesn't really capture our motivation for building the super collider. Elementary particles in themselves are not so interesting, at least not in the way that people are interesting. I like to say that if you've seen one electron, you've seen them all. We study these particles as a means to an end, the end of finding the fundamental principles that govern all types of matter and force. It is principles, not particles, that we are after.

By the mid 1970s we had worked out a pretty good theory, known as the standard model, that accounted for all of the forces and particles we could study with existing facilities. But the standard model is not a final theory; it has too many arbitrary features, and it leaves out important things, like the force of gravity. Fortunately

the standard model itself tells us where to look for clues to a deeper theory. You see, the predictions of the standard model work well at the energies of present-day accelerators, but when we try to use the standard model to predict what will happen at twenty times higher energy we get nonsense—absurdities like infinite forces or negative probabilities. In other words, the standard model is itself telling us that there have to be new forces and particles that are not included in the standard model but are needed to make a consistent theory, and that will definitely have to turn up when we can study particle collisions at 20 times the energies that are now available—which is why the super collider was designed to reach these energies.

This is unusual. In the past, most new accelerators have been built on the assumption that with increasing energy interesting new phenomena were bound to turn up, an assumption that has almost always turned out to be correct. With the super collider we are in a better position—it is guaranteed to discover something really new.

We have tentative ideas about what these expected new particles would be like. Most of them are highly unstable, which is why I said that they have been absent since the first trillionth of a second of the universe. But in the most promising of the theories that try to go beyond the standard model there exists one exception; a type of particle (sometimes called the neutralino) that would be stable, and would therefore have survived the big bang in very large numbers. There already is a hint of this from astronomy; studies of galaxies suggest that most of the mass of the universe is not in the form of ordinary matter. The super collider would be able to discover these neutralinos if they exist, and in this way it would tell us at last what our universe is made of.

Virtually everyone agrees that good, interesting science would be done at the super collider. Some scientists, however, have been anxious to point out that this sort of elementary particle physics is no more important than other branches of science, such as their own, with which they feel the super collider competes for funds. I think this sort of argument is unfortunate. For one thing, the competition is largely imaginary; in the past, when funds have been cut from the super collider program they have not gone into other branches of science. Also, I don't think that elementary particle physicists claim that their branch of science is more important than any other. (In fact, I'm reaching an age at which I am beginning to think that research on the prostate gland is more important than anything else.) But I would argue that elementary particle physics does have a distinctive and unique of importance.

I can illustrate this by comparing two different scientific problems. First, in elementary particle physics we have been worrying for years about what it is that gives the known elementary particle the masses they have. We know that it has something to do with the new types of particle that would be discovered by the super collider, but we don't know much more than that. Second, in condensed matter physics (the field of Professor Anderson) there is a problem of the peculiar behaviour of certain materials that remain superconducting up to surprisingly high temperature. Both problems are fascinating, and they actually involve some of the same mathematical ideas; indeed, some elementary particle physicists have recently been crossing disciplinary boundaries to work on high temperature superconductivity. But there is a difference. When high temperature superconductivity is understood; whatever ingenious experiments or imaginative theories it will take to understand it, the explanation will take the form of a mathematical demonstration that this phenomenon is a consequence of properties of electrons, atomic nuclei, and electromagnetic forces, properties that are already known, and that in turn can be explained in terms of the standard model. On the other hand, when we come to understand the origin of the masses of the elementary particles, it will be in terms of new principles that are at present entirely mysterious, and that we cannot learn without new data. In this sense, in elementary particle physics we stand at the frontier of scientific knowledge, in a way that is not true of any other branch of science. No one would say that this gives elementary particle physics a right to a first charge on the public purse, but it is a factor that deserves to be taken into account in decisions on public funding of science.

Many of us think that if we keep tracing our explanations to deeper and deeper levels, if we keep pushing back the frontier of scientific knowledge, then sooner or later we will come to a final theory, a set of simple principles that govern everything in the universe. Certainly our theories have become steadily simpler, explaining more and more in terms of fewer and fewer fundamental principles. We can not promise that the clues that will be provided by the super collider will lead immediately to a final theory. But with the super collider we can start to move again toward our goal.

I had the honor to testify in Senate hearings in 1987 (incidentally, before the decision was made to site the super collider in Texas.) In preparing my statement for today's hearings, I read over the statement I made in 1987, and I was struck by how little has changed. At that time I explained that we theoretical physicists were stuck; we seemed to be unable to go beyond our present theories without new data. Now, six years later, without new high-energy data, we are still stuck. No technological obstacles have been discovered that would compromise the super collider's success. There is also no change in our judgment that the super collider is what is needed for us to be able to continue the historic process of uncovering the fundamental properties of matter and force. It has become more apparent than ever that there is no other way of breaking out of the fundamental impasse facing physics. The reason that particle physicists want the super collider built is not that it will help us do our work more easily, or more quickly, but that without it we cannot make progress at all.

One thing that has changed since 1987 is that the super collider is becoming a reality—contracts have been awarded, farmers and homeowners have been relocated, magnets have been built and tested, tunnels have been dug, and thousands of man-years and over a billion dollars have been spent. So why is the Congress even considering abandoning this program? I have heard a number of reasons offered, but none of them make any sense to me.

Some critics of the super collider point to supposed mismanagement and cost overruns. I am not involved in the management of the super collider, except as an unpaid advisor, and I am much less able to take up these issues than are some of the witnesses you will hear this afternoon. But after hearing some of the accusations about mismanagement of the super collider I did my best to look into the matter. I would like to go on record here as saying that in my opinion there has been no mismanagement at the super collider. None. There has in fact been good progress in all areas of construction. With regard to cost increases, one hears talk of increases from $4 billion to $11 billion. These figures are not honest. The original estimate of the total project cost, if converted from 1986 dollars to dollars as spent, was $5.9 billion. In response to technological and site-specific requirements and a stretchout of the project from 8 to 10 years, this did go up in 1990 to $8.249 billion. This figure has not changed since 1990—if the project received the projected yearly funding, it could still be built for $8.249 billion. (In fact, costs have been running a little under the original estimates.) If the program is stretched out again, the cost will naturally go up again. If you stretch out the program enough, any scientific project can be made as expensive as you like.

Some people, while admitting that in the abstract the super collider is worth its cost, argue that we just can't afford it right now. But there is something fishy about this argument. Whenever we start a project of this size, there is bound to be some time during the years it takes to complete the project when the economy will be bad. What should we do—keep starting large projects, only to terminate them whenever there is a downturn in the economy? If we write off the investment already made in the super collider, and put off the project until better times, what scientists or foreign governments would want to participate in such a project, when it might be cancelled whenever the economy is bad again? Certainly any program should be reconsidered if changes in science or technology warrant it. Indeed, it was the high energy physicists who took the lead in cancelling ISABELLE, the last big accelerator project, when changes in physics goals made that appropriate. But if the super collider is cancelled after all the work done on it, just because the economy is bad right now, then we may as well say goodbye to any hope of ever having a responsible program of research in high energy physics.

Then there are some people who would do not think that the United States should support research in high energy physics at all. Some of those who are arguing against building the super collider also argued against building the previous generation of accelerators, which have turned out to be outstandingly successful. Most disturbingly, I have heard several Congressmen say that they cannot defend expenditures on any scientific research that does not promise immediate economic or medical or military applications. There may be more at stake here than just the super collider.

For centuries the relations between science and society have been governed by a tacit bargain. Scientists generally want to make discoveries that are universal, or beautiful, or that push back the frontiers of knowledge, whether or not they can foresee any specific benefit to society. Society has historically been willing to support this sort of pure science because experience shows that great scientific discoveries have unexpected applications, and the effort to make these discoveries forces us into a sort of technological and intellectual athleticism, that leads to other applications. The trouble that the super collider now faces in Congress is just one symptom of

a general unravelling of this bargain, that we see also in the attempt to re-orient the National Science Foundation toward societal needs. To advance our technological society, we need to continue the support of pure as well as applied science. And does any program of support for pure science make sense if it excludes high energy physics, which alone pushes back the frontiers of scientific knowledge to search for nature's ultimate laws?

The CHAIRMAN. Thank you very much, Dr. Weinberg. We will go vote, and we will come immediately back.

[Recess.]

The CHAIRMAN. The hearing will come to order. Our next witness is also a distinguished Nobel laureate. Professor Philip P. Anderson from the Department of Physics, I think that is Applied Physics, at Princeton University.

Welcome, Dr. Anderson. Please proceed.

STATEMENT OF DR. PHILIP W. ANDERSON, DEPARTMENT OF PHYSICS, PRINCETON UNIVERSITY, PRINCETON, NJ

Dr. ANDERSON. Let me actually throw away the introductory material I have here for myself and say a couple of things. One is that I think there is a concealed conspiracy here somewhere. Senator Johnston and this committee, and the Democratic National Committee are the only two people who give me the middle initial "P" when my actual middle initial is "W". And I receive a lot of mail from the Democratic National Committee to Phil P. Anderson.

[Laughter.]

Dr. ANDERSON. And I am not an applied physicist. I like to call myself a fundamental physicist as well. I just am fundamental in somewhat different ways.

The CHAIRMAN. Was that because of the W particle?

Dr. ANDERSON. No, it is only the Higgs boson that I helped invent.

What I can say is that I am perhaps the only person in this room, and perhaps I am being a little indiscrete there, but I am one of the people in this room who has actually contributed both to the theory of superconductivity and made major developments in that, and made major developments in nuclear magnetic resonance. And I am sorry Senator Specter is not here because I not only talk about nuclear magnetic resonance, but in my early years I did something about it. And I believe some of my ideas are actually incorporated in present day MRI spectrometers.

Now, on several occasions over the years I have testified against the SSC and against other big science projects, and in favor of funding a wider variety of fundamental science on a peer reviewed basis through institutions such as the NSF and NIH which have a good record of responsible distribution of funds.

Now, I am very conscious that, as the chairman said, we have all been through this twice before at least, and so I will try to be as brief as possible, and just remind you of the kind of argument I have given in the past rather than to flesh them out in full detail. In any case, I do not think that I can be any where near as eloquent as my colleague here, Steve Weinberg.

Dr. WEINBERG. You could try.

[Laughter.]

Dr. ANDERSON. On this occasion I particularly want to emphasize that I do not oppose the SSC for the reasons that it is scientifically

unsound or badly mismanaged. On the scientific soundness I agree with almost all of what Steve has said. On the mismanagement, I am not as closely connected with the inside of the project but I know enough to know that it would be very surprising if the accusations on this matter were really completely true.

I want to disassociate myself from this kind of attack on the project because, in the one case, I know it is not true, and in the other case I have no inside knowledge.

Accusations of this sort could appropriately be made about Space Station Freedom, as Senator Bumpers has pointed out, and I think it is something of a scandal that the House has chosen to support the scientifically unsound and technologically uninteresting manned space program rather than the SSC. The manned space program has much more fantastically overblown claims of its useful spinoffs.

I well understand that the questions the SSC is designed to answer are deep, fundamental, and interesting; and also that if the scientists were allowed to carry out their job without interference, they would probably do so very efficiently. I do not agree with Steve that it is the only way that that job can be done. I think that that represents something of a failure of imagination.

The point of my testimony is that of priorities. The physics being done by the SSC is a very narrow rather specialized area of physics with a very narrow focus. It focuses on the very tiny and very energetic sub-sub-substructure of the world in which we live. Most of that substructure is well understood in a very definite sense. Nothing discovered by the SSC can, for the foreseeable future, change the way we work or think about the world and cannot change even nuclear physics.

Perhaps a couple of hundred theorists—which, in my impression, is too many thinking about such a relatively small fraction of science—and a few thousand, one thousand or a few thousand experimentalists work in this particular field of science. That is less than 10 percent of the research physicists in the world, and a much tinier fraction of all the research scientists. Yet the budget for this operation dwarfs the budget of all the rest of physics. The fact is that particle physicists are funded, on the average, 10 times as liberally as other physicists. The science, per scientist, is given 10 times as much money. In this sense, the SSC is not a very efficient jobs program, at least for scientists.

At least two books, and many articles, have been recently published trying to justify the special status for this particular branch of physics as somehow more fundamental than all other fundamental science. That so many particle physicists have time to write such books and articles may tell you something about the real interest in the field; it has not made much progress lately, and so they do not have anything else to do.

There are many other really exciting fundamental questions which science can hope to answer and which people like myself are, on the whole, too busy to write books about. There are questions like how did life begin? Why is biological catalysis so efficient? What is the origin of the human race? How does the brain work? What is the theory of the immune system? Is there a science of economics?

All these have in common that they are manifestations not of the simplest things about matter, the simplest fundamental particles and the tiniest parts of the particles, they are manifestations of the complexity of matter and energy as we ordinarily run into them. These manifestations of complexity do not, cannot to my understanding, have any possibility of being affected by whatever the SSC may discover. On the other hand, the future seems to me to belong to these subjects, to these questions, rather than to the infinite regression of following the tiny substructure of matter.

For another example of a very different kind, since I wrote this testimony a fundamental question of mathematics which has puzzled scientists for over 3 centuries was solved, namely Fermat's Last Theorem. In what sense can one really say that the mathematics that was used to solve this question is less fundamental than the physics that is involved in the SSC? This is simply an impossible question to answer, and I think the answer is if you could do it, both of them would be worth whatever they cost. But if you have other priorities on your cost, perhaps you should think which fundamental questions are easier and less expensive to solve.

In all of these other questions, there is the possibility of serendipity. You may find something useful and you may find something you were not looking for. The study of real intelligence is bound to tell you things about artificial intelligence, for instance. The theory of the immune system can tell you things about many awful diseases, and in particular AIDS but also many others.

The deep questions of biology lead to bioengineering. The deep questions of solid-state physics lead to materials engineering in the way that I just described when I said I worked on deep questions of nuclear magnetic resonance, they are now applicable in magnetic resonance imagine. This kind of relevance to practical questions and serendipity, the possibility of finding things that you did not expect to find, is what a large and very inflexible machine such as the Superconducting Super Collider does not have.

Now, particle physicists, naturally, are deeply concerned about the problems of the funding and the health of their field. So are the rest of us. We feel that in no sense is particle physics the one special field in which it is essential for the United States to stay ahead. If there is such an essential field, I would argue that it is not particle physics, but one of those I mentioned above. The playing field in deciding between different projects of science should be level. It should not be heavily tilted in favor of one powerful group, which is powerful, really, only for historical reasons.

This group did not choose to consult with its international colleagues or with the community of physics as a whole before deciding on the particular course of action that they took. Is it any wonder that many of the rest of us believe that a decision as to where the frontiers are, what are the important frontiers, and what has first priority on the public purse should all along have involved the whole of science and the whole of the subject of physics which, I assure you, some of the rest of us own as well as the particle physicists? We were never asked to go along with this project, and

perhaps it is not surprising that we therefore dig in our heels and make something of a point of our opposition to it.

Thank you.

[The prepared statement of Dr. Anderson follows:]

PREPARED STATEMENT OF DR. PHILIP W. ANDERSON, DEPARTMENT OF PHYSICS, PRINCETON UNIVERSITY, PRINCETON, NJ

My name is Philip Anderson, Joseph Henry Professor of Physics at Princeton University. I worked for many years at AT&T Bell Labs, ending up with the rank of Director on my retirement, and I was a Professor at Cambridge University for a number of years. I won the Nobel Prize in 1977 for fundamental research in solid state physics. I may be the physicist most often cited by colleagues.

On several occasions over the years I have testified against the SSC and other Big Science projects, and in favor of funding a wider variety of fundamental science on a peer-reviewed basis, through institutions such as the NSF and the NIH which have a good record of responsible distribution of funds.

I want, on this occasion, particularly to emphasize that I do not oppose the SSC because it is scientifically unsound or badly mismanaged. Both of these accusations have been made in Congress and in the press, and I want to disassociate myself absolutely from them. These accusations should appropriately be made about Space Station Freedom, and I think it a scandal that the House has chosen to support the scientifically unsound and technologically uninteresting manned space program rather than the SSC, on the basis of fantastically overblown claims of its useful spinoffs. I well understand that the questions the SSC is designed to answer are deep, fundamental, and interesting; and that if the scientists were allowed to carry out their job without bureaucratic interference, they would do so efficiently.

The point of my testimony is that of priorities. The physics being done by the SSC is a very narrow specialized area, with a very narrow focus: on the very tiny and very energetic sub-sub-substructure of the world in which we live. Most of that substructure is well-understood, in the sense that nothing discovered by the SSC will, for the foreseeable future, change the way we work with or think about the world; it cannot change even nuclear physics. Perhaps a couple of hundred theorists—too many, indeed, thinking about such a restricted subject—and a thousand or so experimentalists work in this particular field of science. That is less than 10% of the research physicists, and a much tinier fraction of the research scientists, in the world. Yet the budget for this operation dwarfs the budget of all the rest of physics: particle physicists are funded, on the average, ten times as liberally as all other physicists. The SSC is not a very efficient jobs program, at least for scientists.

At least two books, and many articles, have been published recently trying to justify this special status for particle physics as somehow more fundamental than all other fundamental science. That so many particle physicists have time to write such books and articles may tell you something about the real interest of the field. There are many other really exciting fundamental questions which science can hope to answer, which people like myself are too busy to write books about:

- How did life begin?
- Why is biological catalysis so efficient?
- What is the origin of the human race?
- How does the brain work?
- What is the theory of the immune system?
- Is there a science of economics?

These are only the most obvious questions for the layman; our field, solid state physics, has many, many fascinating and fundamental unsolved mysteries, which are to my mind no less fundamental as to how matter and energy interact in the world around us than the deep interior of the fundamental particles.

In all of these other questions, there is the possibility of serendipity; you may find something useful, or something you weren't looking for. The study of intelligence is bound to tell you things about artificial intelligence, for instant. The theory of the immune system can tell you things about many awful diseases, not just AIDS. The deep questions of biology lead to bioengineering, the deep questions of solid state physics to materials engineering. This kind of relevance and serendipity is what a large inflexible machine such as the SSC does not have.

Particle physicists, naturally, are deeply concerned about the problems of funding and the health of their field. But so are the rest of us; and we feel that in no sense is particle physics the one special field in which it is essential for the U.S. to "stay ahead." If there is such an essential field, I would argue that it is among those I

mentioned above. The playing field should be level, not heavily tilted in favor of one historically powerful group.

The CHAIRMAN. Thank you very much, Dr. Anderson.

Our final witness on this morning's panel will be Mr. Robert Galvin, who is chairman of the executive committee of Motorola, Inc., and long a national and international leader in applied technology.

Mr. Galvin.

STATEMENT OF ROBERT W. GALVIN, CHAIRMAN, EXECUTIVE COMMITTEE, MOTOROLA, INC., SCHAUMBURG, IL

Mr. GALVIN. Thank you, Bennett. I am going to be a little more intimate because we seem to have a one-on-one discussion here, although I know you will be representing your colleagues on the committee. I appear here with, in effect, two roles. One, I am the vice chairman of the URA, and I am an executive of Motorola of some 50 plus years in the application of science.

Let me start by attempting to, in effect, capture one's attention by saying science will cure cancer and science is the magic bullet that will multiply and enhance our economy. We just do not know at any one particular point in time and exactly how those class of results are going to occur, but the sooner the better. We would like to have the cure sooner, and we would like to have a more vital economy sooner.

I have testified before this committee before and I am going to give you a very new and unique message here today in terms of, in effect, an anecdote, something one can scenario with. But it is, in effect, just a means of attempting to capture ones attention to the other subjects that I have addressed in the written testimony which I will not amplify hardly at all here.

In particular, referencing the superb contribution of Dr. Panofsky, who has written to this committee and I hope that his outstanding analysis of the situation from his vantage point of the chairman of the board of overseers of the super collider will be given high cognizance.

I also speak to the issue of group dynamics in my testimony, and I respectfully suggest, sir, that whenever the words hearing or oversight or investigation or audit come out of the city of Washington,. D.C., it causes reactions of people and I think that there can very well be at least one significant ingredient having to do with the apparent conduct of people at the super collider site having to do with responses to inquiries, et cetera.

People get scared, sir. I have seen it happen in my company and I have seen it happen when people in our company have been looked at in terms of ASPRA regulations, and unnatural but normal things take place. I respectfully suggest, sir, there are some bits and pieces of information here that are worthy of the committee's consideration.

But let me give you an interesting anecdote, and I just made it up as I was sitting here this morning.

[Laughter.]

Mr. GALVIN. Everybody says they want this thing if it is the perfect world and if we can afford it. I am sure Dr. Anderson would agree, if we could afford all the funds for NSF—and I am all for

those and more—and other things at the various Government laboratories. If we could allegedly afford those things, we ought to do them. In my estimation they are readily affordable.

But let me just give you a construction, and it is a construction. I am contriving a construction for you so we can have some cocktail talk, so to speak. Motorola would not exist as a significant, world class, rapidly growing, highly profitable, energetically employing institution today if it were not for the recent developments, meaning over the last 50 years, of science that trace themselves all the way back to, incidentally, the mathematicians that Dr. Anderson spoke of like Turing of England who set the stage of mathematics for Neumann to give us the computer, and Radon who gave us the mathematics that gave us the ability to think out the theory of tomography.

These people, individual scientists, are all the roots from which people like us have finally created very significant economic engines. Motorola is in the semiconductor business. We build products from subatomic materials. We need to know more about subatomic materials in order to make our business vastly more dynamic and larger than it is today.

Let me give you a couple of numbers. It will not be long, only a couple of years from now, that Motorola will be spending $2 billion for its engineering and research. About half of that—in fact, we will spending more than $2 billion, but something approaching half of that will ultimately translate itself into income tax payments to the U.S. Government if you trace through the flow of money. So $500 million is going to be paid to the U.S. Government some time around the turn of the century as a function of the dynamics of Motorola, who are paying money to engineers.

And I know that I am contriving something that is not a realistic thing. Our money should go into the national Treasury and for all purposes. But if one were to just pretend that that money was allocated to the expenses of the super collider which were represented to be a half a billion dollars a year, just the survival of Motorola makes payable the expenses of running the super collider in the year 2000 or 2001 or 2002 or 2004 or what have you. I deal in round numbers, but I think relevant and within the ballpark of appropriate estimations.

But companies like ours and Intel and Texas Instruments and National and Harris, who got a nice report in the paper this morning, we would not exist if it was not for the scientific developments of just yesterday. Now, I do not know that we are going to get the key to the next new development out of the super collider. Statistically, we may not, somebody else will get something very significant. But we probably will, and we will get things out of NSF.

And our business, sir, is going to be ranked in the terms of trillions of dollars in the lifetime of my children and grandchildren, not billions. But it is only possible because we have the science base from which to create these economic benefits that translate into all the political factors that you people are aspiring to. You cannot get there by wishing it; you have to have knowledge, you have to have building blocks.

And it is, frankly, just a few companies like ours—and I do not want you to spend the money for Motorola's benefit, but we are smart enough to take every advantage out of it we can and so should every other private sector institution do so. But the more that knowledge is available for people who can reach out and grab and do things with this, we are going to make this one hell of a lot better country and a lot better world. But we cannot do it without scientific knowledge, and with it, sir, we make it readily and early affordable.

Every political leader in this city has to be awfully glad that there is as much dynamics in this economy today as there is. You can complain that it is not quite buoyant enough, but thank God it exists to the degree it does. And a great deal of it is based on scientific knowledge that all came along in the course of mostly this century, and that is recent times.

So I say bet on this science. Have faith in this science. Science has never let us down. We take the aggregate of all the things that are taught from whatever branch of science, and some of us will find ways of exploiting it honorably and to the best interests of our society.

[The prepared statement of Mr. Galvin follows:]

PREPARED STATEMENT OF ROBERT W. GALVIN, CHAIRMAN, EXECUTIVE COMMITTEE, MOTOROLA, INC., SCHAUMBURG, IL

Mr. Chairman and members of the committee, thank you for the privilege of testifying in the interest of the Superconducting Super Collider. I present myself as one wearing two hats.

I have recently become the Vice Chairman of the Board of Trustees of Universities Research Association, and I am Chairman of the Executive Committee of Motorola, Inc.

The Board of Trustees of Universities Research Association is charged with the broad responsibility and oversight of construction and performance of the Superconducting Super Collider Laboratory. The Board is elected by members of the corporation that is composed of many scores of America's most distinguished scientific educational institutions.

My career with Motorola Inc. extends over half a century; the majority of that time as the Chief Executive Officer of that company. Motorola is a high technology company. I hope to illustrate the relevance of advanced scientific knowledge to economic development as implemented by high technology private sector interests.

This written testimony is relatively short for a practical reason. Dr. Wolfgang K.H. Panofsky, the retired director of the Stanford Linear Accelerator Center, has submitted written testimony. Dr. Panofsky has served as Chairman of the Board of Overseers for the Superconducting Super Collider. URA structure provides an overall Board of Trustees for the corporation and then a separate Board of Overseers for each of the two principal laboratories under the cognizance of URA. One of these is the SSC Laboratory and the other is the Fermi National Accelerator Laboratory (Fermilab) in Illinois.

He has gone to extensive lengths to prepare the class of material that we deal with as board members. I simply associate with everything that he has so skillfully portrayed in his testimony and do not elect to redundantly restate the fine case that he makes for the following topics:

1. URA is the experienced and successful contractor for designing and building large basic science facilities. The successful Fermilab experience is a particular credit. Indeed, URA is the only corporation in the United States that has successfully built a superconducting collider; the Tevatron at Fermilab is now the leading world accelerator in energy and luminosity and extremely important research is being conducted there by scientists from all over the world.

2. The integration of building and designing such complex facilities is essential.

3. Management and operations contracts are an eminently successful methodology in managing this class of project.

4. It is important to evaluate a project this complex as a system involving, not only the management of construction and the laboratory, but also equal

consideration of the technical performance and scientific merit of the ongoing activity.

5. Dr. Panofsky analyzes the prematurely released reports of the Inspector General and others. He makes the point that a further factual review casts a different and more favorable light on the well controlled progress of the project.

6. A different modus operandi regarding the monitoring of the laboratory from the various central Federal agencies could both improve the understanding of the status of affairs and make the ongoing operations more effective and efficient.

7. Illustrations are provided of practical modus operandis between the SSC Laboratory and other Government laboratories which justify that wise choices were made in the execution of the supply arrangements. The investigative reports may be misinterpreting what has been a creditable set of sourcing experiences, particularly in the procuring of magnets, that was not fully understood by those who engaged in the investigatory role.

8. Dr. Panofsky respectfully suggests that the issue of management allowances may be being handled more appropriately than was realized upon first review.

9. The Laboratory's Integrated Project Management Control System is now operational and will be further refined in the next six months in preparation for validation by the Department of Energy. But, even in the early stages of the project before this complex system was operational, there was a sufficient system of controls to manage costs intelligently and to tabulate value added and to make appropriate projections. Nevertheless, URA and all of us who are associated with the project are dedicated to having the optimum system and being fully compliant to the requirements of the senior officials of our Federal establishments.

Dr. Panofsky made other salient references which can be referenced in the question/answer and discussion period of the hearings.

I will now present for the written record two additional observations.

First: As a leader in a high technology industry, I have made the point before this committee previously and continue to state in public forums that many high technology industries depend on the building blocks of subatomic matter for development of new products and services.

Without the science base of new knowledge regarding subatomic matter, we will be limited in our ability to engineer the next levels of sophisticated products for tomorrow's markets. This is particularly evident in the semiconductor field. It is true in many others.

Science gives us our technology base. The broader the base that we have available, the more options will be available to our engineers to come up with important new applications.

Without the science of yesterday, the transistor would never have been conceived. Without the transistor and all of the semiconductor derivatives, the great things that we see going on about us today, both for economic development in the United States and in services to markets all over the world, would never have been attained.

Public policy people who can build parts of their public strategies on the vitality of the economy that exists today must appreciate that others had the long-term vision to have supported science yesterday for today's benefit. We cannot say to ourselves today that we can put off the needs for tomorrow. The price and time are right.

Naturally, we must have faith that the discoveries of new truths about the laws of nature will convert into an applicable technology. We have never lost our bet with that kind of faith in the past.

Our economy in not too many years in the future will be driven by the seeds of new science and will be inhibited if those seeds are not nurtured.

Second: I wish to comment on a sensitive subject that deals with the impression garnered by Federal officials that members of the staff of the super collider were less cooperative and/or purposely resisting the answering of the appropriate inquires of various investigative and oversight efforts of recent months.

For whatever reason of such conduct that may have taken place or may have appeared to take place, the leadership of URA is intolerant. It is our policy and it is our reinforced policy that all members of the staff will be cooperative.

I have devoted a modest amount of personal time to ask about this situation from a few but not a broad cadre of people in the laboratory and I catch the hint that some part of this problem derives from the simple but serious phenomenon of fear.

As an institutional leader, I have seen how this can influence people's conduct without their hardly realizing it. Many years ago, our company was investigated for apparent misinterpretation of certain Department of Defense regulations in the conduct of certain processes and activities counter to particular ASP regulations. On the one hand, it didn't make any significant difference to America's defense of

freedom and certainly no one ever profited by such an incorrect application of a regulation but as a matter of fact, we were not in order regarding some of those regulations.

The point I wish to make is that the investigative experience caused human reactions that were apparently all too natural by the people involved. I can safely say that everyone of our people intended to be honorable about everything they had done having presumed that their interpretation of what they had done was appropriate and ethical. But, once it was questioned they became fearful of both their careers and the possibility of criminal implications of their conduct.

It took considerable human relation skills to finally get everyone into a mood of confidence that their objective dealing with the situation did not place them at risk.

As one who tries to understand the people aspect to the optimum degree, I respectfully suggest that this kind of reaction is not uncommon, and to the extent that it confused the situation during a given period of time, one should not interpret that this was an overt effort to be noncompliant and noncooperative.

The activities in the super collider entity are so complex, so demanding and so important that I respectfully suggest that people are key. I submit that virtually all have the highest order of honorable intentions. In an atmosphere free from free and undue uncertainty, the inherent positive attitudes will prevail.

An official of the Department of Energy saw the matter from a different perspective. He said that he has never seen a group of people who worked harder than the talented staff of the SSC laboratory. They are dedicated and cooperative, but they have been subjected to unusually intensive oversight and multiple reviews and audits. Regretfully, it is only human if a person working intensively on a difficult project may occasionally resent interruption and be uncooperative with the queries of auditors. URA has urged its employees to be fully responsive in the future. We believe that the misunderstandings that have existed are being corrected and that this problem of human relationships should not decrease our commitment to the completion of the most important laboratory in the most fundamental field of science.

In conclusion, the need for scientific discovery is essential. The opportunity for dramatic and positive success at the SSC is confidently predictable. The important scientific discoveries at the SSC will be combined with scientific results for the nation's broad based program to produce the technology on which the further growth of our industry depends. The manner in which we are going about the designing and the instrumenting of this great new tool for science is on track. It is my fervent hope that we will, as a citizenry, recast our support for the mission of the project and the organization to achieve it.

The CHAIRMAN. Thank you very much, Mr. Galvin. I knew we would not be disappointed. We have another vote. Let me go vote and I will return immediately.

[Recess.]

The CHAIRMAN. The hearing will resume. Gentlemen, we apologize again for the interruption.

Dr. Anderson, you know a whole lot more about physics, probably, than you know about how this place works up here. Physics is a whole lot more logical and organized than we are around here.

One of the fundamental debates that we sometimes have is over whether science ought to be all put in one committee and whether the scientific community ought to be organized into one group like the American Physical Society, and that that group ought to make all decisions with respect to science, and prioritize all of science. My answer to that is, yes, they should, and I ought to be in charge of it.

[Laughter.]

The CHAIRMAN. Unfortunately, this is the Committee on Energy and Water Appropriations. We have a good part of the science, high energy physics, we have fusion, we have the national labs, which have much of the science which goes on in the country we have jurisdiction over and much we do not.

Indeed, in the scientific community there seems not to be a great deal of unanimity about what ought to be done, as witnessed by the fact that you disagree with the American Physical Society's verdict on this particular project, which is not—I am advised by scientists that that is not unusual in some groups, that scientists tend to put more importance in what they are doing than the field of someone else. That is a scientific phenomenon in the scientific community, is it not?

Dr. ANDERSON. Well, in the first place, I do not think the American Physical Society has absolutely come out for or against the SSC, because I think that they made a statement that it was too bad for this reason or that reason. I do not believe they said—and particularly at the beginning at the origin of the project that the American Physical Society gave the SSC any endorsement whatsoever because they were not asked to.

There was strong opinion in the council of the APS suggesting that the American Physical Society prioritize different projects, and that was voted down, because I think that—well, I will not speculate as to why, but it was voted down, so I do not think that there has ever been a statement by the American Physical Society saying that this project has first priority among all the projects that they support.

I have written a recent editorial, or a recent column in Physics Today advocating that perhaps it is time that we started something more unified in the way of a science-governmental structure, because I am very aware of the anomalous status of all of the sciences in different bits and pieces of committees, that there is great fragmentation.

I do not think that it would be so much of a problem. After all, we have—we heard from Jack Gibbons, who represents all of science, and I have not really heard serious complaints that the pressures, the directions that he chooses as important are very bad, while we may differ on the SSC slightly, I am not sure deeply, but I think it is possible to find more unified, better prioritization than we have had in the past, and that, of course, is what I would really urge.

I am as aware as Steve is that your choice is to decide for the SSC and against some water project or against some other—something which to me seems irrelevant, but perhaps—and of course, it is not irrelevant, because it is your responsibility to the Government to spend the Government's money wisely, that part of it that you have.

The CHAIRMAN. Well, the points that I were going to make are two. First, that in our disorganized system up here, you understand that this does not compete with the National Science Foundation and NIH, except in a very indirect sense, coming as it does in a different jurisdictional appropriations subcommittee, so that if we kill this, this money would not revert to one of those, it would revert, as you say, to another water project, and you indicate you understand that.

You are aware, of course, that the American Physical Society have their statement here from June 26, 1992: "The Executive Board of the American Physical Society is dismayed by the recent vote of the U.S. House of Representatives to terminate funding for

the Superconducting Super Collider," and they go on to say that "Cancellation of such a highly visible project would send a message to the world that the United States is relinquishing its longstanding commitment to the fundamental scientific research."

I take it—my real question to you, I guess, is—and I understand your statement on priority, and it is a very legitimate one, and you come to this committee with tremendous credentials and great ability to speak about science and everyone, including Professor Weinberg, who tells me yesterday that you are really very good friends and you enjoy sparring on some of these things—but you come with great credentials, but I ask you, sir, is there not a point in a project where, even if it was not of the highest priority, to cancel the project would send a terrible message to the world that we are relinquishing our role in science just as the American Physical Society says? Is there not a point in this or other projects where you reach that?

Dr. ANDERSON. Well, as you say, the American Physical Society made this—I am sure it was a judgment call for many of their people. I might have made it slightly differently, but I certainly sympathize with the point of view that they were taking.

The CHAIRMAN. That was June 26, 1992. This is August 1993. If they were right then, they are surely more right now.

Dr. ANDERSON. I did not say they were right. I said I understand why.

The CHAIRMAN. The point is, there is a point in a project—I do not know where you would put that point. There is a point in there somewhere where you would say it is wrong to terminate, and then, of course, my next question would be, where is that point with this project? We have had two big debates in the Senate. They added another $1 billion, $2 billion into this, 7,000 employees hired, 12 miles of tunneling, we have got 2,000 scientists with their lives on the line.

Where is the point in the project that you can say a Nation has made a decision to—what do you call it, basic fundamental science, answers that are deep, fundamental, and interesting, and we have decided as a Nation to find out the answers to what you call deep, fundamental and interesting science.

Is not the American Physical Society—if they were not right last year, are they not right now?

Dr. ANDERSON. I think the answer is, if it is going to be terminated, it is better now than later, and it would have been better last year than this year, but of course, it is up to you. The actual decision is up to you.

I am here to present a particular point of view, and I will make you aware of the fact that I—and I am not alone. There are, perhaps—at least on the order of half of the members of the American Physical Society would agree with me that it will not be the end of science, or even the end of physics, if it is stopped.

The CHAIRMAN. Well, certainly that is true. You would agree that it is probably the end of high energy physics as we know it, though.

Dr. ANDERSON. It probably is not even that. There is still CERN, and there is still the possibility of collaboration between the Europeans and ourselves. There are various other ways in which the job can be done.

The CHAIRMAN. Well, you know, there was a large debate about whether CERN at collisions at what, 15 trillion electron volts—is that the power?—is not sufficient, is that correct?

Dr. WEINBERG. 8-on-8, two beams of 8.

The CHAIRMAN. Double, so 16 is not a sufficient energy, which is why we have got collisions here at 20 doubled at 40. Was that a sound scientific judgment, in your view?

Dr. ANDERSON. I personally would have done it in a more gradual way. I would have seen what happened at 8-on-8, and then I would have gone to 20-on-20, rather than precipitously jumping into this project the way it was done without proper consultation either with the Europeans or with the rest of the physics community.

The CHAIRMAN. Let me ask you one final question, Dr. Anderson. Senator Bumpers talked about research which is arcane and indefinite, meaning that it is not exactly applied science. I gather that you would disagree, since you say that we ought to look at how life began, the origin of the human race, and some of those things. Those are not exactly applied science. You do see a place for basic science in this country, do you not?

Dr. ANDERSON. Well, I spent most, or a great deal of my working life at the AT&T Bell Labs as a fundamental scientist. I worked in basic science without ever any direct applied work, yet as I said, many of the things I did eventually had an application, so in my own life I have lived the scenario that Mr. Galvin and Steve were talking about of working on fundamental science and having it turn out to be useful.

The CHAIRMAN. When, at the time you were doing it?

Dr. ANDERSON. Yes.

The CHAIRMAN. It was, as Senator Bumpers would say, arcane and indefinite.

Dr. ANDERSON. It was an arcane—but on the other hand my bosses at Bell Labs were intelligent enough to see that work in this field could eventually lead to practical applications, and they were right.

I make the same judgment about the SSC, and I see it does not probably lead to practical applications, and there are other things that one could do that would, even though they were fundamental or basic science.

The CHAIRMAN. Professor Weinberg, we have had some talk on the floor of the Senate, some of it slightly divisive, about the Big Bang theory, as if that were an irrelevancy and some arcane, uninteresting thing. What percentage of the scientific community, those who deal with, I guess, high energy physics, or cosmology, or whatever, accept the Big Bang theory?

Dr. WEINBERG. I have not taken a poll, sir, but I suspect it is about 99 percent.

Dr. ANDERSON. I agree.

Dr. WEINBERG. It is the working consensus. You know, we are not asked to swear our allegiance to a particular dogma. What matters is what we use in our work. That is really where the decision is made, what you believe in.

You take this as something which, if you believe it as true, your work will be advanced. Almost all working astronomers,

cosmologists, elementary particle physicists, have come around—some of us with some reluctance, because in fact I used to prefer a different theory myself—to the feeling that the experimental evidence for this is overwhelming, and we would be dopes not to take it as true.

The CHAIRMAN. Professor Anderson, you were shaking your head. You agree with that.

Dr. ANDERSON. I was certainly agreeing. I was adding in my own mind thermodynamics and information scientists as well as astronomers, cosmologists, and so on.

Dr. WEINBERG. Can I take that as a friendly amendment?

Dr. ANDERSON. We would not be alive and we could not think if it had not been for the Big Bang.

The CHAIRMAN. I think it is not only interesting but important to go into it, because I think there is some reluctance among some Americans, and even some Senators, to almost ask the question, because they see some sort of religious significance in the Big Bang theory.

I personally think it is entirely significant—I mean, entirely consistent with Genesis, if that is your concern, but the point is, it is well-accepted, and the significance of it at the SSC is that the last time these forces existed, and therefore these particles, was in the first nanosecond, or whenever it was after the Big Bang.

Dr. WEINBERG. If I could just slightly sharpen that, the particles have not existed in appreciable numbers since the Universe was about a trillionth of a second old.

The forces are there now, and they are actually what is giving the electrons and the quarks inside your body the masses they have, so it is relevant to the present world, but the particles which the theory of these forces make mathematically necessary do not happen to be around in the Universe today.

It is a distinction between what exists as a mathematical consequence of the theory and what actually happens to be around in nature. The particles are not around now because they decayed long ago. The forces which require the existence of these particles are around. They are acting inside the nucleus of the atoms inside you and me, and that is what we are trying to get at.

Senator Bumpers in his comments earlier made the remark that—he asked the question, is it not possible that when we build a super collider we will not find anything new, and since he is back, I would like to answer it and say, no, it is not possible. It is just simply not possible.

We know that electrons and quarks have masses. We know that forces are producing it, and we know, because we can prove it mathematically, that these particles which are required by the existence of these forces have to turn up at energies which can be reached at the super collider. That is why the super collider is being built to have the energy it does.

What we do not know, of course, is exactly which particles—which of the competing theories is the right theory, but we know—and this is unusual for an accelerator. We are not usually in a position of being able to say this, but we know that we will find these very exciting and fundamental things at the super collider if—if it is built.

The CHAIRMAN. Professor Weinberg, would you tell us about the Higgs boson and the origin of mass and why those two things are interrelated?

Dr. WEINBERG. Well, I can try.

The CHAIRMAN. I think you are equal to the task, because you have told me before, although I do not remember exactly what you said.

[Laughter.]

Dr. WEINBERG. You know there are symmetries in nature. Many of them are familiar to us. The laws of nature do not make any fundamental distinction between up and down. It happens that there is a gravitational field which pulls us down, but we know that is because the Earth is down now.

At the level of the fundamental equations, there is no fundamental distinction. We do not have in our equations some reflection of whether you are looking up or down. It is just, if you happen to be on top of something, then you fall down rather than up. The symmetry between up and down is broken by the presence of the Earth. It produces a gravitational force that pulls us down.

Well, there are other symmetries that are less obvious, and only recently we have discovered symmetries that are not symmetries between different directions in space but symmetries between different types of particle, and they, too, are fundamental symmetries at the level of the underlying equations. They really are built into the book of rules that governs the Universe, but they are not obvious.

For example, there is a symmetry between two particles called the electron and the neutrino, but if you look at the particles in the laboratory, they do not look that similar. Something is breaking the symmetry. The same way the Earth pulling us down breaks the symmetry between up and down, there are fields that pervade the Universe that break the symmetry between, for example, the electron and the neutrino, and in the most successful theory of the weak and electromagnetic interactions we make speculations about what those fields are.

The CHAIRMAN. That is where you earned your Nobel Prize.

Dr. WEINBERG. Yes. It had something to do with that, yes.

We know that some fields like this must exist because of the obvious fact the electron has mass, the neutrino does not, so we are not talking about something that is a wild speculation. It has got to be there. We do not know the details.

I would love it—I am a theorist. I do not do experiments. I would love it if I could solve all these problems myself and you would not have to build a super collider. I am not smart enough, and no one else is. We have to get the answers experimentally.

Every time you have a field, it is manifested also as a particle. For example, the electromagnetic field, the force that—for example, the magnetic force that pulls particles around in the ring in the super collider is also manifested as particles, particles called photons, which make up a ray of light. This we have known since 1905.

Well, this field that is responsible for the breaking of the symmetry and responsible for the mass of the electron and the quarks and all of the other particles has to show up as particles,

and we can say some things about them that we know, and other things we do not know, and one of these particles in the most popular theory, which happens to be the one that you referred to kindly that I was associated with, the one that appears in the most popular theory is called the Higgs boson, and that is—if that is the right result, then that would be found at the super collider.

But there are competing theories, but one thing we know is that all of these particles which are little bundles of the energy of the fields which break the symmetries which give the particles the mass—I almost said which Jack built—all of these particles have masses less than a certain amount, and it is low enough that they can be produced at the super collider.

Can I make a remark following up on something Phil Anderson said? He and I agree on so many things that I do not want to get into a dog fight with him. I certainly agree that the kind of physics he does, smaller scale physics, is wonderfully interesting. Not only is it of practical importance but it is intellectually exciting.

You mentioned that the physics community was not asked to go along with the super collider. I was not asked to go along with your research, Phil. If I had been I would have been happy to go along with it, but nobody asked me. But I think we have to do a lot of different things. We have to do that kind of physics and we have to explore the outer frontier, and that outer frontier has gotten expensive. I cannot help it, it just has.

Phil says that the only way that we can do this kind of research, answer these fundamental questions about mass and the origin of mass and the breaking of symmetries—he says that our statement that the super collider is the only to do it reflects the failure of imagination. Well, Phil is nothing if not consistent, because he made the same arguments back in 1970 when the question was whether to build Fermi Lab and CERN and that generation of big accelerators.

In fact, at that time he argued that what we need is not more big accelerators to answer the fundamental problems. He listed a number of fundamental problems, by the way: The peculiar hierarchy of broken symmetries; the missing and impossible W-meson; divergences—he said the way to answer these questions is not build more accelerators but a new conceptual revolution.

In fact, what happened is society went ahead and built those accelerators and all of those questions were answered as a result of the interplay of theory and experiment, with the experiments being from those accelerators. We now have the answers to just those questions, and we have it as a result of building Fermi Lab and CERN. We would not have those answers if we had not built those accelerators.

We are not mindless building larger and larger accelerators because we enjoy it. For 15 years we have been stuck without the data that we need from the next generation of accelerators. And believe me, we would love to do this sort of thing without spending so much of your money and our time building accelerators, but we do not know how to do it.

You know, I am a small science person myself. My support is from the National Science Foundation, not from the Department of Energy, so I do not owe you guys anything.

Senator BUMPERS. That is a two-way street.

[Laughter.]

Dr. WEINBERG. Well, wait.

This is my scientific instrument, and it did not cost the taxpayer a penny because I stole it from the hotel.

I think we need some way of making sure we support science at the kind of level that Phil Anderson is talking about. I do not know whether we need a Department of Science or what. We do not have a mechanism.

The high energy physicists did come to a conclusion within their community. This seems to work, that scientists within any one area that share common goals can prioritize. The astronomers did it with the field report. They recommended this observatory have highest priority, the next one the next highest, those recommendations were largely followed.

The high energy physicists also prioritized. We said we will give up Isabelle. We want to go for something that will really answer our questions. That is what we did. That was the start of the super collider. It is very hard to prioritize between different communities that have different goals, because the goals are incommensurate. How do you compare the discover of the origin of life with the origin of mass? I do not know now to make the comparison. That is your job.

What we have to do, it seems to me, is to present our case as well as we can, and then leave it to the public and their representatives to make that decision. I am a little skeptical about any grand system of prioritizing all of science, but maybe something along that line is possible.

I think I have answered much more than your question.

The CHAIRMAN. That was very good, Professor Weinberg.

Mr. Galvin, we talked about what we would discover and what the importance of the SSC is. Could you comment on what the American physical society calls the—"cancellation of such a highly visible project would send a message to the world that the United States is relinquishing its long-standing commitment to fundamental science research."

Could you comment on the downside of what a decision to cancel this project would mean in your view?

Mr. GALVIN. Well, I am not a science analyzer and I do not know those people intimately. I do think I understand group dynamics about as well as lots of other people do. And as soon as we send signals to any public that we do not need them to the same extent that we had otherwise been telling them that they were respected and important, it does diminish the degree to which resources will then be assigned.

And as a matter of fact, physicists will tell you right now that as a function of the fact that they cannot get enough jobs, that that is beginning to turn off people's intentions as to who will go to what schools in the future. Let us all go to law schools or political science schools, if that is where the jobs are.

So I think that the signal would be a telling one to the rank engineers as well as the most sophisticated of the scientists if this was turned off. But in my estimation that is a significant question, in my estimation the other ones that we have been discussing are

even more important, and we do need the diversity of the study of whatever science is available to study because it will pay back in giant proportions in reasonable time, as I attempted to anecdote with my simple little story of the fact that there would not have been the Motorolas if there had not been the investments of yesteryear.

The CHAIRMAN. Senator Bumpers.

Senator BUMPERS. Thank you, Mr. Chairman.

Dr. Weinberg, there is not anything in this research that we are looking for that is not going to be there 30 years from now, is there?

Dr. WEINBERG. Well, the universe will be here 30 years from now.

Senator BUMPERS. We hope.

Dr. WEINBERG. I do not know if there will be any physicists working at the frontier of physics 30 years from now if we do not build the super collider now. But the particles will still be there, no question about that.

Senator BUMPERS. Well, I find that some particle physicists sort of poo-pooed the CERN project, and I am not qualified to say whether they are right or wrong. But I do not know of anybody that is out there trying to build anything comparable to what we are talking about here. So therefore, I do not think we are going to get behind if we do not do it right now.

Dr. WEINBERG. Well, I do not think this is an arms race that we are in. There are two possibilities, Senator, and I really do not know which one will happen if we do not build the super collider. One possibility is that our friends in Europe and Japan will go ahead with the plans they have been discussing. There has been no decision to build the machine at CERN. And I do not know the way that decision will go.

That is what I hope, of course. I mean, if we do not build the super collider, I will then urge as strongly as I can that the Japanese and the Europeans do go ahead, because I care more about the science than I do about where the science is produced. Then, we will have some of our best young scientists getting on planes and spending their working lives in Japan and Europe.

The European accelerator—that is the one that is most concrete now—may not answer any fundamental questions. You know, what you said about the super collider, that it is possible it will not discover anything new, that was not true of the super collider. It is true of the CERN machine. And it is not because their judgment is different from ours. It is not because they decided 8 billion electron volts is a more sensible target than 20. It is because they have an existing tunnel and they are trying to fit the accelerator into an existing tunnel, and 8 is the highest energy they can get.

Actually, they are pushing the state of the art beyond what might even be prudent, although I am not sure about that. They are getting the highest field magnets they can into that tunnel, and they cannot get more than 8 billion volts—8 trillion, sorry. I am going back to my childhood when I say billion.

Senator BUMPERS. We are shooting for 20? We are shooting for 20?

Dr. WEINBERG. Yes. We are shooting for 20, because that was a scientifically determined target. From zero to 20 is like a room in which something is lost. We know it is in the room. If we only search up to 8 then we are looking at about a third of the room. We might find it, we might not. You can calculate the chances. But I still would urge our European friends to build it.

Then what we would see is that the great American tradition of high energy physics was over, that the most exciting news in the outer frontier of physics was coming from Europe or Japan, and that would be sad. But the science would continue.

The alternative, which I think is more likely but I am not sure, is that although the scientists would be more eager than ever to build a super collider, the European Governments would draw the conclusion that since the Americans were not going to build it they were not going to, either.

You know, there has been a reciprocity between America and Europe. We say that there is no international collaboration. But you should really put the word formal in that there is no formal international collaboration. In fact, American scientists going to CERN use the CERN facilities even though America did not spend a penny in building the CERN accelerator. The reason that they are allowed to do that is not because of an international treaty but because of an understanding that European scientists have the same privilege in American accelerator laboratories.

A large part of the most exciting discoveries at CERN were done by Americans. And likewise, many of the groups that are trying to build up to work at the super collider are Europeans. Well, if America is not going to carry its share, if we are going to opt out of this field, then I think that understanding will come into question. I cannot see the European Governments forever making CERN open to American scientists on the basis of just the merit of the scientific work if America does not have comparable facilities.

I think physics will go into the state that astronomy is in now, where the astronomers who get to use the telescopes are the ones whose governments helped to build the telescope. So you have a British-French-Canadian telescope and you have an American-Australian telescope. But you do not have, really, international telescopes. We may go in that direction with America left out of it.

Senator BUMPERS. Dr. Weinberg, if we build the collider and we find precisely what we are looking for, that just calls for another collider, does it not?

Dr. WEINBERG. I hope not. Even particle physicists have a lot of effrontery. I do not think I would want to propose anything right now, anyway, beyond the super collider. But I think if we build the super collider we will find these exciting new particles. We do not know which ones, so I cannot tell you what direction research will take. It may be that the hinges will snap shut in our minds and we will see what the final theory is and then we will be able to tell you "No, we do not need any more, Congressman; spend it on something else."

Particle physics is almost unique among—I think it probably is unique among all branches of science, that we are the one branch of science that is working to put ourselves out of business. We

would like to come to a final theory which would mean the end of particle physics. We do not work on these particles because it is fun, but because we have an historic aim in mind.

We do not know that we will reach it with the super collider. We sure would like to. But if we do not, as well may be the case, we do not know which direction we will have to go. But I would say you are talking about something that is perhaps 40 years into the future, because the super collider has a very long useful lifetime.

It is true that after the super collider reaps the initial harvest, we can then come back and say well, we would like to improve the magnetic field and go up to a higher energy without having to build a new tunnel or anything else at a relatively small cost. So it is an expandable project.

Senator BUMPERS. Professor Weinberg, let me read something to you.

Dr. WEINBERG. Please.

Senator BUMPERS. "Not even the SSC nor its successors will approach the ultimate quest of the origin of the universe. To recreate the temperature of the universe at its birth we will need an accelerator light years in size. That does not mean, however, that we cannot learn the nature of the infant universe." Do you agree or disagree with that?

Dr. WEINBERG. I agree with that if you emphasize one word: I think there was a word directly in there. The super collider, nor any accelerator that I can imagine, is going to get up to the temperatures—well, obviously, nothing can get up to the temperatures of the very beginning of the universe because that was infinite. So clearly, no accelerator is going to be able to get up to an infinite energy. And I will grant you that point. I will stipulate to that.

Senator BUMPERS. Let the record show that it is Dr. Sheldon Glashow, Nobel laureate.

Dr. WEINBERG. Sheldon, yes. He is a good friend. There are questions having to do with the nature of gravitation also that probably cannot be addressed directly by any accelerator. However, remember the last sentence Glashow said, that this does not mean that we will not be able to understand these things. I do not have the words in front of me, but you have quoted something to that effect.

We will be able to understand these things, not by getting up to the energy where gravity becomes a strong force, but intellectually, just as we are never going to be able to get out to the distant quasar which we see 10 billion light years away. But we understand them through the normal process of extrapolation of scientific information. We have to continue the process because if we stop now we know we will not make any progress toward understanding the origin of the universe.

We are not going to recreate another universe in an accelerator lab. I stipulate to that.

Senator BUMPERS. Dr. Weinberg, I was sitting in my office a while ago and you said you wished I were here so I could attack you.

[Laughter.]

Dr. WEINBERG. Glad you heard that, sir.

Senator BUMPERS. Well, I did not come here to attack you. I came here to try to illicit information. I note you said you were a theorist. That is a very enviable position to be in. And with it we have a $4 trillion debt as a result of some economic theorists around here whose theory somehow or other went awry. And there have been a host of us trying to bite the bullet ever since then.

I might also say there were a host of us who did not buy into that theory in the first place.

Dr. WEINBERG. Nor did it.

Senator BUMPERS. Well, you may be a better guy than I think, then.

[Laughter.]

Senator BUMPERS. But let me reiterate something you said in your testimony. "I would like to go on record here as saying in my opinion there has been no mismanagement of a super collider—none."

Dr. WEINBERG. That is right.

Senator BUMPERS. Now, I have a report here which has not been released that has been compiled by the Super Collider Laboratory Project Management Control System. And they say, number one, that "the design and implementation is late in relation to the project's duration. At the time of this review, the PMCS continues to experience data quality, system design, and unresolved management policy issues which limits the effectiveness of current reporting for assessing current project status, completion costs, and expected schedule."

They go ahead to say, "Despite the fact that the project is 4 years old"—the PMCS—"that the DOE team reviewed is in its adolescence in terms of its functional implementation." And then finally, they say, "The ultimate improvement in system utility as a project management decision tool is dependent upon three key management decisions, which are:

"1. Rebaseline the project;

"2. Institute an environment where a proactive and comprehensive estimate at completion process is encouraged and routinely performed; and

"3. Establish a joint DOE/SSCL policy for management reserve and contingency."

And earlier, the DOE had said that they did not have a sufficient system there to even determine—to even determine—how well they were doing in managing the project, that there were virtually no ways to determine what cost controls, if any, there were. As a matter of fact, they could find none.

And the report goes on to say, "There is a disclaimer at the beginning of the monthly progress report, as indicated in the SSC self assessment review, the PMCS. Now this refers to the University Research Association. They say that they put a disclaimer, a disclaimer notice on the front cover of each monthly report, rejecting the, accuracy, completeness, or usefulness of the information, and that that clearly sends the wrong message regarding the contents of the report.

Now, if you were the U.S. Government or a U.S. Senator and you were getting monthly reports from a project manager saying we make no representations as to the integrity or honesty of this

report, would you still believe that there had been no mismanagement?

Dr. WEINBERG. Well, I would like to answer.

Senator BUMPERS. I am not talking about people stealing, Dr. Weinberg. I am talking about people's competence.

Dr. WEINBERG. In the first place, the air has been filled in the last few months with tentative reports which somehow get to the press with unpublished—you are quoting from something as a not-yet-published report. I have not seen it. I do not know who has seen it.

Senator BUMPERS. I just read it to you.

Dr. WEINBERG. I do not know to what extent you are reading out of context. I do not know to what extent it represents what the report finally will say. I know, for example, there was a GAO report which came out and was widely quoted, and then a month later it turned out to be much milder and more favorable than it had been originally. I think it is about time to stop running up the walls every time someone leaks a report which is not in its final form. And so that is a procedural point.

Senator BUMPERS. Well, suppose this report is in its final form, Dr. Weinberg.

Dr. WEINBERG. Well, I have not seen it. It has not been circulated. I do not think it has been answered by the laboratory management. And I do not know to what—but I will try to give a substantive answer. I have looked through the GAO report and the Inspector General's report, because I am curious about this. I am not a management expert. I hardly know what some of these things mean. But my impression is—and this applies particularly to what you were quoting—that almost all the complaints have been complaints about the creation of accounting systems and cost-prediction systems, and have not been complaints about the actual building of the laboratory.

In fact, as I understand it, the Department of Energy has a statement now that the laboratory is 20 percent complete and 20 percent of the cost has been spent with very little taken from the contingency fund, much less than 20 percent. So objectively the laboratory is going ahead, the magnets are being designed, the tunnel is being dug. The costs that are being spent are very reasonable. I mean, they fit what was projected.

What the complaints are is that there is not a cost-prediction system in place which some accountant thinks ought to be in place. Now, I do not know that much about cost-prediction systems, but I looked into that a little bit. As I understand it, there was an old cost-prediction system the Department of Energy has used for many years and it worked fine, and some people at the laboratory thought that they could do better with a newer system and use the old system in the meantime. The newer system took a while to come on line and they had some trouble bringing it on line.

I am glad you said that there is no problem with dishonesty, but there is no problem of misspending of funds, and there is no problem of actual cost overruns. The problems you are referring to, if they are real at all and I am not sure they are, are problems of accounting and foreseeing future costs. The lab management may have made a decision that it was more important to actually hire

the best people, design magnets the best way they can, and go ahead with the job and do it as well as they can, rather than creating a paper trail which would satisfy every possible critic. And if I had been in their shoes, I would have made the same decision.

They are operating according to the same procedures that produced Fermi Lab; they produced our national laboratories, that have worked very well. The general record of high-energy physics has been that high energy physics projects have had overruns not more than a few percent, 3 percent I remember a figure. It seems to me that there is an effort being made to replace the system that gave us Fermi Lab with the system that gave us the B–1 Bomber.

Senator BUMPERS. You took the words right out of my mouth. That is what always happens around here. Not the B–1, but the B–2. The B–1 was bad enough, but the B–2, SDI, the space station, and now the collider, it is always the same old story.

If you were in my place, Dr. Weinberg—take yourself out of the position of being a theorist for a moment and place yourself before the Little Rock Chamber of Commerce and defending the funding for this project which started out at $4.4 billion until 6 years later a DOE compliance team says that they do not even have a system in place from which we can calculate what the ultimate cost is going to be. And you expect me to keep voting for funding for a project like that?

Dr. WEINBERG. Well, I am glad you asked that, because these figures have floated around. The use of the $4.4 billion figure, it is just amazing to me that that figure survives.

Senator BUMPERS. Well, take the $13.2 billion, take any figure you want.

Dr. WEINBERG. I will come to that one too. The first time that there was a calculation of the total project cost in terms of dollars as spent was the figure was $5.9 billion, not $4.4 billion. The $4.4 billion figure did exist at one point, but it was in 1986 dollars. If they had calculated in 1786 dollars it would have been considerably less. It was not in dollars as spent, and furthermore it was not the total project, it was a subpart of the project.

There is now a well-defined project and we can follow the costs of that project. The first time those costs were calculated with a site in mind, the costs were $5.9 billion. It did go up. There is no question, it went up from $5.9 billion to $8.249 billion. And if the spending profile had been what had been anticipated in that plan, it could be built for $8.249 billion or less, because some of the costs are coming in lower than anticipated.

Any other increase has to do with costs for stretching out. If you want to stretch it out to the year 2050, the cost will be anything you say it is. The $13 billion figure is a fictitious figure representing someone's guess about some stretch-out which we have not yet determined. I think if you talk about cost increases, there was a cost increase from $5.9 billion to $8.249 billion, and that itself was partly due to a stretch-out from 8 to 10 years and it was partly due to technological developments which made it necessary.

In fact, that decision to increase the cost at that point represented the laboratory's judgment that we did not want to go the way of the Hubbell Space Telescope. The Hubbell Space

Telescope, in order to keep costs to an absolute level, sacrificed testing their mirrors, and as a result we have a marred instrument. Some of the increase from $5.9 billion to $8.249 billion went into increasing the aperture of the magnets to make sure that the magnetic field would have a high enough quality so that the machine would do what is promised.

Senator BUMPERS. Let me interrupt you, Dr. Weinberg.

Dr. WEINBERG. Yes, sorry. I go on too long.

Senator BUMPERS. I know exactly what you are saying, and I am not suggesting that we have been deceived. I am not even suggesting that we have been misled. We have been given erroneous information. I am not saying the people who gave it to us were trying to deceive us. What I am saying is I sat right here in this seat in 1987 and seriously pondered this super collider, thinking maybe this is a good idea.

But I can tell you categorically, based on what I know around here, the argument on the floor of the Senate will be quite at odds with what you are saying. The argument on the Senate floor will be it has all been fixed, we have a new management team. All those abuses of the past have been corrected. I saw it in SDI, I saw it in the B–2 Bomber, I see it in the space station today, and I will see it on the floor when we debate this.

The arguments you are making, I am not suggesting that somebody lied, though they may have, but here you have, you know, another view saying they do not even have a cost-control system in place where they can give us any idea of what the ultimate cost is going to be.

Dr. WEINBERG. That is your quotation of it, Senator. I have heard you quoting other things. I do not have any way of judging whether or not the report in its final form will say that.

Senator BUMPERS. Well, I do not know whether it will or not either, but I can tell you I do not have the luxury of sitting here saying I am going to vote for the super collider no matter whether this is right or wrong or regardless of what the cost is going to be.

Dr. WEINBERG. No, I do not think you should do that.

Senator BUMPERS. At some point Congress is entitled to some kind of a definitive answer about what this thing is going to cost. Is there any point at which you would be opposed to the collider from a cost standpoint?

Dr. WEINBERG. Sure.

Senator BUMPERS. Where is it?

Dr. WEINBERG. I am American citizen. I have not decided. I do not think we should spend $100 billion on it. I mean I do not know. Between $100 billion and what, I really have not come to that decision.

Yes, of course there is a point at which it is too expensive. I have other concerns in life besides elementary particle physics. But this is not an example of a project that has had runaway cost increases. What we face is runaway stretch-outs which can, in fact, increase the cost.

You say that you have to tell your colleagues in the Senate we do not know how much it is going to cost. That is absolutely right, you do not know how much it is going to cost because you have not made up your mind how fast you are going to build it. When you

make up your mind how fast you are going to build it, then we can tell you how much it is going to cost. If you built it at the rate that was originally projected, it would cost $8.249 billion or less.

Senator BUMPERS. Dr. Weinberg, we have been told every year since this thing was conjured up what it was going to cost, and every year it has been wrong. We are now talking about——

Dr. WEINBERG. That is not true. The figures have not changed in the last few years.

Senator BUMPERS. You are talking about $8.9 billion.

Dr. WEINBERG. $8.249 billion.

Senator BUMPERS. $8.249 billion.

Dr. WEINBERG. Yes. That figure has not changed for several years.

Senator BUMPERS. Well, how do you account for the fact that GAO says it is going to cost $13.2 billion? I mean they did not fall off a turnip truck either.

Dr. WEINBERG. GAO, I would first of all not regard as a impartial observer of this. They were asked to do a job by certain Congressmen, and GAO does what the Congressmen ask them to do. In the second place, they did not say it would cost $13. something billion. There was a GAO report—there were several GAO reports. If they used the figure $13. something billion—I do not know where they did—then it was in connection with a completely hypothetical plan for stretching out the project. It was not on the basis of the original schedule of the project.

If you built the project at the original schedule it would cost $8.249 billion. GAO might have said it would cost $15 billion, on the basis of some other plan for stretching out the project. Of course you do not know what it is going to cost if you do not tell us how fast we are going to be allowed to build it. But there is no $13 billion figure that has any status as an actually carefully calculated figure on the basis of an agreed plan of building it.

Senator BUMPERS. Are you suggesting in your testimony that by stretching the completion date by 2 years, the cost went from $5.9 billion to $8.249 billion?

Dr. WEINBERG. No, I did not suggest that. I said that was part of it, part of the reason for the cost. And I was very careful. I said part of the reason was that, and I said part of the reason was the discovery of a technological need as a result of computer simulations to increase the magnet aperture from 4 to 5 centimeters.

And I was on the committee that recommended doing that. We knew that it would cost a few hundred million dollars more. I think that was about a third of that increase. And the reason we did it was because, as I said, we did not want to go the Hubbell route. We did not want to keep the cost fixed and then have an instrument that did not work properly, so we accepted the necessity of recommending a higher—that was about a third of that increase.

A third of it was the stretch-out. And then there were recalculations due to the fact that—I am sorry, my mind is a blank, I do not remember what the other third was. There are people this afternoon that could answer that. But that is the cost increase from

$5.9 billion to $8.249 billion, and anything else has to do with stretch-out and is hypothetical.

Senator BUMPERS. Well, the latest stretch-out was announced by the President recently, and I think he extended it by 3 or 4 years, I forget how much.

Dr. WEINBERG. Well, it certainly lowers the cost per year. And, you know, if that is the way we will get it built, that is fine. I mean it is not fine, but that is what we have to live with. I may not live to find the answer of the origin of mass.

Senator BUMPERS. Mr. Chairman, I will not belabor this any more.

Dr. Anderson, I am sorry. You and I are on the same wavelength. I did not ask you any questions. And, Mr. Galvin, it is always pleasant to have you here. This is deja vu, having all you gentlemen here. I do not know that anybody has learned anything much from this except—with no exceptions.

The CHAIRMAN. We have learned we were right.

[Laughter.]

The CHAIRMAN. By the way, the GAO report from February 1993 which states on page 3—they talk about: "Trend analyses show the cost of completion for architecture and engineering services, conventional construction, will be $630 million over the baseline cost estimate of $1.25 billion. However, because DoE does not have a fully functioning cost and schedule control system, it is not clear how much these costs will change the project's total cost and schedule."

I am advised that their estimate of $630 million has been revised to a $40 million underrun using the same scope of work which I state for the record. Which does not necessarily make it so, but it does show that these are dynamic, changeable figures.

The committee then will stand in recess until 2:30.

[Whereupon, at 1:21 p.m., the hearing recessed, to reconvene at 2:30 p.m.]

AFTERNOON SESSION

The CHAIRMAN. The hearing will come to order.

This morning, Madam Secretary, we had a very interesting morning with Dr. Jack Gibbons, Director of the Office of Science and Technology Policy along with two distinguished Nobel laureates, Steve Weinberg and Phil Anderson, and a distinguished captain of industry, Bob Galvin from Motorola, who in various ways talked about the importance of science, and the vote was 75 percent for the superconductor, and that is a pretty good margin.

This morning we made our opening statements and we dealt largely with the science of the project, and we now have the piece de resistance, the Secretary of Energy, and we are glad to have you back before the committee, so please proceed.

STATEMENT OF HON. HAZEL R. O'LEARY, SECRETARY, DEPARTMENT OF ENERGY

Secretary O'LEARY. Thank you very much, Mr. Chairman. I want to begin by saying I would like to improve on that percentage that you just described as 75 percent in favor, and in so doing I want to begin in a relatively dramatic way for me.

Now, I have got to point out for this committee and the assembled audience that I read my Washington Post this morning, and I want to assure you that it is not my intention, nor has it ever been my intention to sacrifice this project, not to any committee nor to any Chair, and I want to tell you at the committee why.

First of all, I believe that this project, this high energy physics project is so important to the United States of America that it cannot be sacrificed, and those who would presume, because I have determined that it needs better management, that that is to lead to sacrifice, do miss the point.

Now, I am not a world-class scientist, nor am I a Nobel prize laureate, but I am one who is responsible for the Department of Energy and its projects, and more importantly the economic drivers that we set in place for the Nation, so I do not want so much to talk about the world class science, because I think that others can do that better, but the piece I do want to talk about that I understand well is the economic driver that the basic science, the high energy physics research in this Nation, has provided to us in America for some 40 years, and that is what this project is all about.

I have vainly sought some way to describe this, as I have said to my grandmother, and I have not figured out the way to describe it to my grandmother, but I know how to describe it to the Nation, and that is to look at all of the high energy physics projects that have gone forward in the United States with the Fermilab and all the way back to each accelerator and each bit of physics study that has been focused on answers to imponderable questions and look now to the outcomes for the Nation.

I must also focus on the fact that here in the United States we have only one margin, one edge left, and my belief is that that is in high energy physics, and it is for that reason that I think that this project cannot be sacrificed.

Now, in so saying, I want to point to things that I think were not described this morning, and that is to put in context this project, again, against things my grandmother does understand, and the way I would do that is, I would focus on things such as the Fermilab, and talk about that project which was started but which now, when one focuses on the Superconducting Super Collider, is some 200 percent larger.

I would now force people to look at the construction project between Great Britain and France, which is the tunnel under the English Channel, which again puts into perspective for me personally and for others, I believe, how large this project is.

When one thinks about the fact that this project was begun on an open field in Texas—and in my business we call that a green field project. That is, we have to come in with some plans and some concepts and some glorious vision and begin, and begin in an area where nothing of this size had been tried before.

Despite the complexity of this project, despite its size and the necessity to marry big construction with huge science, we are today, by examination within the Department of Energy, on schedule and, I believe, on budget.

Now, the reason I believe that is that we have had a team of some 30-odd people out taking a very hard look at this project to

answer the question which is often asked in construction projects of this size, and that is, have you received value for the thing on which you have spent your money? I.e., is the project on time, and has the money been spent in the way that was planned? We know that that is true.

More importantly, I need now to focus on the very unique management structure that was created to get this enormous high science program and this huge construction project, for which there are few proxies, done.

When the Department of Energy decided back in the late eighties that this was the project, and that Congress approved it, I believe that the sitting Secretary of Energy, too, recognized the tremendous challenge before him both in the science and within the construction, and requests for bids were sent to 121 companies that were deemed to be appropriate for doing this kind of business.

Interestingly enough, only one responded, and that is the current contractor, U. A—University Research Association. With that one response, even at that point the leadership in the Department of Energy recognized that while there was the excellent reputation in managing the high science and there had been the experience at the Fermilab, that the size, the exponential size and growth in size of this project required something more, so even at that time back in 1988, a contractor with construction capability and experience was added to the team to attempt to balance that piece off.

Something else happened as well, and I think that has to do with the recognition that the project was unique. That something else that happened was that that project was moved out of the normal scope of the Department of Energy's oversight and review for scientific and construction projects and made to report dually both to the Director of Energy Research and to the Secretary of Energy.

Having sat in the job now for some 7 months, I can tell you that that is a very unique and also very awkward set of reporting relationships.

What happened next in the Department of Energy is that this project was removed from the normal cycle of scrutiny for business practices within the Department so as to give it more careful attention. It occurs to me in hindsight that this was perhaps inappropriate and, indeed, has led to some of the concerns that I have had with respect to the management oversight, and it has been that that I have spoken of.

All that aside, I want to reflect once again upon the fact that the project is on schedule. The project is on schedule and value has been received for what the Government and the taxpayers have expended money.

Now, I have indeed stated that I am understanding the concerns raised by both the GAO and our own IG. I do believe, however, that the methodology, especially, that the GAO has used to move forward now and to embrace a figure with respect to cost overruns is, quite frankly, inappropriate. It makes any number of assumptions with which I cannot go along, and I want now to describe to you why.

I have indicated that a management team has been on-site for approximately 3, almost 4 weeks, reviewing the very business practices and, if you will, the audit trail that allowed them to come

to the conclusion that we have received as taxpayers value for the project. In so doing, they have discovered some things that I believe need management attention to cause this project to be run much more efficiently. Here is what they were asked to do.

No. 1, they were asked to review the paper trail and indicate, as I have told you, whether we got what they said we got and they paid for what they said they paid. The answer to that piece was yes, we are where we should be, we will be 20 percent complete by the end of September, and we have gotten value for the money expended.

However, that examination took much longer than it should have taken. That examination was not—it was not capable to conduct that examination by simply going in and asking, let me see your roll-up books with respect to accounting, with respect to your business plans, with respect to your project progress.

As I am understanding it from two briefings and not yet having read a report which is incomplete, is that the management systems in place are not fully integrated, i.e., do not integrate across program and project components, and more importantly, do not integrate from the manager on-site up to the manager who has now to review the paper. That, in my view, needs correction.

The next question we asked our managers to look at was, and is, whether or not those management systems that one would expect to be in place to permit a very quick review are in place—I will cite you an example. If one were going off to another project or laboratory, that review could be completed in 3 to 5 days—whether those systems, which have been called management control systems, and you have received that report, are yet in place, we know the answer to that. No, they are not. There have been stops and starts.

It is critical that that piece be completed and you have and the committee has available to them some 50 recommendations with respect to how we can pull that system together. I think that that needs to occur, that will occur, and that is again a good management practice that I, as Secretary of Energy, would expect to occur.

Finally, in this review and examination we also asked the question, where are there costs and management risks that are liable to lead to the project's cost being much greater than one has anticipated? I did not ask that question to punish anyone nor to criticize anyone, but because good contract and project management requires knowing where those risks are so that you can manage and reduce those risks, or much more importantly, manage and erase those risks altogether.

What we found in that portion of the review is that there are indeed risks existing which, if left unattended, might cause this contract to be much more expensive than we have contemplated. My view as the manager, the chief manager of this Department is that I would have an expectation that the contractor in charge, with oversight from the Department, would now use this examination to set priorities with respect to how to manage to reduce cost, and that is what I would expect to happen.

Now, a month ago and 2 days ago, or maybe it was 4 days ago, I indicated that in my view, having looked at this contract

relationship, that my sense was that the contract relationship needed to be changed, and I also committed that by Friday last I would have a design to do that.

The 30 days that have transpired and allowed that team to be on site make me more certain that we do need to make adjustments in the contract relationships, and my formal testimony proposes that readjustment, and I would like, with your indulgence, to walk through that before I am finally silent and open to questions.

No. 1, it remains clear to me, and more clear after this review, that the University Research Association are the right team to be responsible for driving the science and the design that relates to science from this project. I was clear on that when I started this examination. I am even more clear of that today.

I suspected a month ago, and I am certain today, that URA needs much more help in managing the business practices of this project, and most importantly, in my view, the construction piece of it, which I have already described as larger than anything I know.

It is therefore the Department and my recommendation, which we intend to move on, to rework the language of this contract such as to permit a partnership, a driver on the science and technical pieces, a driver on the design and the integration, if you will, of this project, which will continue to be URA, but to find available to the Government the very best project manager who has experience in dealing with projects of this size to implement the business practices that I believe need to be put in place to ensure that this project not only continues but continues on budget, and to the extent that we can that we find more value to be driven from the project so that we can drive the price down even further.

Now, having said that, I do not want to leave this committee with the impression that this is a very simple thing to do, because it is not. The one finding from this examination conducted over the past 4 months that is, to me, the most crucial, is the issue of how you integrate all of this work, and those who have heard me talk about it before and all of us know that there are some 40,000 separate work packages to be both completed, tracked, to be financed, have a business plan for, and to understand how to control in terms of ordering progress on work.

My sense is that that is very delicate work that must be negotiated between the driver—that is, those with the scientific concept to understand what they are ordering, what they are designing, what they are desiring—and those who build it, and if I have found upon examination any area in which we have failed, it has been in that integrated piece.

Now, in so saying, I point out to this committee and the public that is a piece that will have to be worked out with URA, the Department of Energy, and that contractor identified to further support this work.

I am just about finished, but my belief is that this project is so important that to proceed without a structure that is much like the one that I have outlined here verbally and outlined more specifically in my testimony would be to put this project at risk, not in terms of completion, but to put this project at risk in terms of

price, and ensuring that the taxpayer and the United States gets value received for this exceptional and very necessary project, and now I am finished.

[The prepared statement of Secretary O'Leary follows:]

PREPARED STATEMENT OF HON. HAZEL R. O'LEARY, SECRETARY, DEPARTMENT OF ENERGY

Mr. Chairman and members of the committee, I am pleased to appear before you today to discuss the Superconducting Super Collider (SSC) program. This morning your Committee received testimony regarding the enormous scientific importance of this project. I share the belief that the SSC is an essential investment in basic science. This project will advance human knowledge through an exploration of uncharted scientific frontiers, and provide real—yet in many cases unanticipated—contributions to United States economic and technological competitiveness.

In my remarks today, I will provide additional thoughts on the value of the SSC to our nation, although you covered that ground well with earlier witnesses. Overall, however, I will speak from the vantage point of my own expertise and responsibilities, namely, management issues and stewardship of the taxpayer's investments.

Specifically, my focus today will be on actions which the Department of Energy has taken during the past month, and additional measures contemplated in the near future, that represent direct and necessary steps aimed at resolving management deficiencies at the SSC. The goal is to ensure first-class management of this vital scientific enterprise.

Before reviewing the details of our planned management changes at the SSC, let me first address issues that lead the Department to determining that management changes were necessary. My fundamental belief is that the scientific potential of the SSC is so important to our nation, our economy, and future generations that the project cannot afford anything less than the best possible project management and financial systems expertise.

I. BUILDING THE SSC: AN HISTORIC OPPORTUNITY AND WORLD-CLASS CHALLENGE

When it first broke ground on the SSC project in the late 1980s, the United States initiated a project of historic scientific importance. The SSC will enable scientists to answer questions that cannot be addressed in any other fashion, questions that bear on the origins of the universe, the fundamental composition of matter, and the forces which explain the world around us.

These are big questions—questions that, as the President's Science Advisor said this morning, are the "culmination of several millennia of human inquiry." The fruits of previous high-energy physics facilities have brought us to the point where we are today: only an accelerator with the size and power levels of the SSC can bring humanity to the next level of understanding of these fundamental issues.

Although one would like to identify specific technological developments and economic returns on the investment that will flow from the SSC, such precision of foresight is not possible. However, if history is any guide, then we can predict with confidence that development of technologies necessary to build the SSC, and the understandings that emerge from experimentation at the facility, will provide major contributions to our economy. Early high-energy accelerators have helped provide break-throughs in health care, such as particle beam devised for medical applications, and in the development of materials that have entered the marketplace, such as semiconductor surfaces embedded by particle beams with thin layers of ions. Indeed, advances in particle physics have affected nearly all aspects of modern life, ranging from national security to energy production to computerization.

Thousands of scientists have devoted years of their lives to the conceptual development and initial execution of the SSC, driven by the certainty that this project represents an invaluable investment both for science and for society. In this fashion, the future of a large portion of today's top, young high energy physicists is at stake with the SSC. This consideration should not be lost in discussions about the fate of this project.

In addition to representing an historic scientific journey, the SSC is one of the largest and most sophisticated construction projects ever. Indeed, the super collider will be the largest scientific instrument ever built, and by far the most powerful accelerator. As a point of comparison, the SSC will be 20 times more powerful than the Tevatron facility at the Fermi National Accelerator Laboratory, which is currently the largest machine of its type. When complete, the SSC will include:

- The largest hard rock tunnel on Earth, with a 54-mile circumference involving 10 million cubic feet of concrete;
- Two subsurface detector halls, each the length of a football field and the height of a seven-story building, containing sophisticated detectors weighing over 25,000 tons apiece;
- Approximately ten thousand superconducting magnets; and
- Two million square feet of office and laboratory space.

The challenge of building the SSC involves not only its sheer size, but also the complexity of the technical requirements. Currently, the project is comprised of more than 40,000 separate work packages, involving thousands of subcontractors. Many of the facility's components, including the tunnel and magnets, must be built to the very precise specifications required to focus beams of protons into a collision area which is only two, ten millionths (2/10,000,000) of a square centimeter in size.

The project represents the marriage of world-class science and world-class construction. This creates a challenge at all levels, including at the Department of Energy Despite these challenges, we believe that we can and will successfully build the SSC, assuming that it receives the continued support of Congress.

II. PROGRESS IN THE PROGRAM

Despite the technical, organizational, and management challenges posed by the super collider project, tremendous progress has been made overall in moving this project toward completion.

The super collider construction began on a "greenfield" site near Waxahachie, Texas, in August 1990. Before major construction work on the project could begin, roads had to be built, land acquired, power acquired, and a myriad of other infrastructure development tasks completed. Furthermore, the organization, management procedures, accounting systems, etc., had to be created.

By the end of next month, the program will be over 20 percent complete. Today, the design work of scientific instruments, equipment, and facilities is largely complete, and construction of the tunnel is proceeding at a rate of approximately one mile a week. Texas has been a valuable financial partner in the project, and has acquired the rights to nearly all of the 16,000 acres of land required for the facility.

Currently, the project involves approximately 2,000 employees—including scientists, engineers, and managers—located in more than one million square feet of office and laboratory space. Over eleven miles of tunnel have already been dug. In addition, the laboratory is becoming a major center for the design, fabrication, and testing of superconducting magnets. The magnets have met their design specifications and General Dynamics, Westinghouse, and Babcock and Wilcox—major subcontractors to the project—are now taking these designs and preparing for mass production of the magnets.

A large infrastructure in industry, academia, and the national laboratories is supporting the SSC. Approximately 1,000 scientists across the nation are involved in developing experiments for the SSC. They are joined by an estimated 1,000 additional scientists from 22 countries around the globe. More than 100 institutions worldwide—including from Korea, Russia, Mexico, China, Britain, Japan, Czechoslovakia, Canada, and all over the United States—are involved in the major international collaborations of this project.

With this progress, the program has become the focal point for much of the world's high energy physics program for the next century.

III. MANAGEMENT OF THE PROGRAM

In August 1988, DOE solicited proposals for an organization to establish, manage and initially operate the Superconducting Super Collider Laboratory. Although 121 copies of the request for proposal were sent to interested organizations, only one response—from Universities Research Association (URA)—was received by the November 4, 1988 deadline.

URA was formed in June 1965 by 34 research universities to provide a nationally-based organization to manage what is now Fermi National Accelerator Laboratory (Fermilab). URA is now comprised of some 80 members and associate members, and continues to manage and operate Fermilab very successfully for the Energy Department.

In order to remedy corporate weaknesses in construction management, URA proposed a team approach with EG&G, Inc. and a small architect and engineering firm as subcontractors. The URA proposal was reviewed and award was made on January 18, 1989.

Project management structure under previous administration

Early in the super collider project, approximately four years ago, the previous Administration decided that the SSC project required a unique oversight and management structure in the Department. A Superconducting Super Collider Project Office was established near the laboratory site in Texas. This office was headed by a Project Manager who was responsible for overseeing the technical health of the project as well as ensuring that progress met scheduled milestones and cost estimates. Unique to this office was that the Project Manager reported not only to the Headquarters Program Director, but directly to the Secretary of Energy as well. It has been explained to me that this arrangement was established to streamline and facilitate day-to-day activities and to assure that the Secretary had direct oversight of the project during the start-up phase.

In 1990, the SSC Project Office was given full delegation of authority for project management, procurement, and personnel actions. Thus, this office has been, in effect, a field office reporting directly to Headquarters. In 1991, the SSC Project Office Director was also named Associate Director of Energy Research for the SSC. The Associate Director maintained direct reporting to the Secretary of Energy as well as to the Director of Energy Research.

This combination of delegation of authorities and the direct reporting relationship to the Secretary created a situation where the project was shielded from normal field office and Headquarters oversight functions. It also clearly diluted the authority of the Director of Energy Research, who would normally have exercised closer control over the project. Other scientific construction projects managed by the Department, such as the Advanced Photon Source and Relativistic Heavy Ion Collider, are subjected to a series of normal reviews which were not done for the SSC. In addition, the SSC Laboratory was shielded from the standard Annual Laboratory Assessment conducted by the Department on all of its other laboratories.

Project management structure under current administration

The SSC project management structure which I inherited upon taking office was flawed in that it removed the project from the normal Departmental management and financial reviews. In addition, the direct reporting line to the Secretary of Energy automatically invited instability with any change in Administrations.

In contrast to how the project previously was structured, I have returned full responsibility for all aspects of the super collider to the Director of Energy Research, and have instructed that the project be subjected to the same oversight and programmatic reviews as other projects. In addition, I have cut formal reporting between the DOE project manager and the Secretary, and also have cut the practice of informal guidance and program directives to the project from the Secretary's office.

Specific management issues

Let me now turn to management issues that have been raised about the SSC.

Earlier I discussed the progress being made in the construction of the super collider. Tunnels are being dug, prototype magnets are being produced, and thousands of dedicated and capable people are pressing forward in the development of what will be a world-class scientific facility. Management of any project, however, demands more than the achievement of technical milestones. Department of Energy Management and Operating Contractors must demonstrate full commitment to openness and accountability. This requires successful implementation of standard financial and business management systems that enable the Department to determine with confidence whether the project is on schedule and on budget. Such systems are a pre-requisite to the goal of being careful stewards of the public money and the public trust. Let me emphasize that such stewardship extends beyond legalistic compliance with the specifics of contract language to a personal and institutional commitment to spend the taxpayer's money carefully.

Specific management problems identified by the General Accounting Office and the Inspector General are listed as an attachment, along with specific actions and timetables that the Department is pursuing to respond to these issues. As the Department has addressed management concerns with the project, it has become clear to all parties involved that the management challenges posed by this project have been larger than previously anticipated.

For example, the importance of implementing a contractually-required Cost and Schedule Control System was not fully recognized by URA. Unfortunately, serious management attention was not focused on this system until late in Fiscal Year 1991. False starts with software packages have also contributed to the delay in system implementation. Although the system is now functioning, it needs considerable maturity before it can produce data that meets the Department's high

standards for cost and schedule projections. Similarly, the SSC Laboratory does not yet have an approved procurement system, which is also required by the contract. In general, URA has fallen short in terms of providing the level of managerial oversight necessary for ensuring that the SSC Laboratory and its subcontractors are performing in a fashion that will meet the technical, budgetary, and schedule milestones that lay ahead.

Although tremendous progress has been made in meeting technical milestones to date, the management milestones have not been fully achieved. As a result, we will be implementing major changes in the project to give it the management excellence that we deem to be necessary for success.

IV. CORRECTIVE MANAGEMENT ACTIONS

A number of actions already have been taken to address management issues raised by the SSC project. These are included in the discussion below.

Project baseline validation

An independent team of Departmental employees, supplemented by outside consultants, is conducting an assessment of the current project cost and schedule baseline to determine the current status of this baseline against the plans which were approved in January 1991. The final results of this assessment are expected within the next few weeks. In a preliminary briefing, the team leader, Mr. John Scango, has informed me that his group was able to validate that the earned value of the project to date is slightly over 20 percent—which is where we should be in this project. However, he also reported that the business systems required to support his review were marginal, that there exist significant risks of cost growth without aggressive management action, and that the present laboratory management is not implementing cost controls and value engineering to contain those risks.

Project management control system compliance review

A separate team of experts consisting of Departmental employees and outside consultants has reviewed the Project Management Control System, and has recently issued its report. In this document, the team concludes that although the system is functional, it is still experiencing start-up problems typical for a system lacking maturity. The group concluded that the SSC Laboratory has a good understanding of the issues and the actions required to correct deficiencies, but that ultimate resolution of these issues will require continued priority from management. Among the issues raised in the team's report are the following:

- The SSC Laboratory organization is still evolving from a laboratory management orientation to one of facility design and construction, and the lack of centralized project management control has impeded the development of the system.
- There has been an inconsistent approach to the development of baseline and working schedules on the project, and there is no apparent top level schedule approval or guidance related to system priorities.
- The linkage of the cost and schedule systems is not complete; this limits ability to produce earned value reports.
- The SSC Laboratory does not have the ability to forecast critical labor resources and manage the project in line with constraints on the availability of those resources.

In all there are approximately 50 specific findings and recommendations to improve the performance of the Project Management and Control System.

Management review and corrective action plan

I have established a team of senior managers and specialists to systematically review all issues which have surfaced concerning the project from various appraisals, audits and investigations which have been performed by Departmental and outside groups. This review will assess progress to date in addressing these issues and recommend further corrective actions to fully rectify these problems. I have requested a report from this group by September 30, 1993.

Equal employment opportunity review

A survey conducted at the project in late June by the Office of Civil Rights of allegations of racial discrimination resulted in preliminary findings that suggest that further analysis of these allegations is needed. Accordingly, I have dispatched a team to the site this week to further investigate these allegations. Further actions will be taken as indicated by the results of this assessment.

Strengthening the Department's project office

In addition to the steps outlined above to strengthen the Department's management and oversight of the project, I have detailed fifteen Departmental staff to Texas to support the Project Office in such functional areas as environment, health, safety, procurement, budget, construction, engineering, and legal. Other assistance will be provided as appropriate in the coming months.

Contractual changes

During the past month, the Department has conducted an extensive review of options for strengthening management of the SSC in the areas of project management control systems, business systems, and subcontractor management. As a result of this review, I am announcing today the Department's intention to: 1) seek modifications in the existing contract with Universities Research Association, in order to focus URA's activities on its clear areas of expertise, and 2) seek a new contract with a firm that will bring to the SSC world-class experience in managing large construction projects.

Under this approach, Universities Research Association remains as the "Design/Operate" Contractor. As such, URA will oversee the scientific aspects of the project, including research, scientific design, commissioning of the accelerator and scientific research equipment, and operations of the facility when complete. The new contractor will be responsible for the project management and control system, business systems, managing existing major subcontracts (including for conventional construction, magnet production, and installation), and compliance with small and minority business requirements.

Most major subcontracts will be transferred to the new "Execute/Integrate" contractor to administer, including: the Parsons-Brinkerhoff/Morrison-Knudsen Team in charge of conventional construction design and management; planned subcontracts for production quantities of superconducting magnets; and a planned subcontract for magnet and accelerator installation.

The Department will renegotiate its current contract with URA to reflect these changes in roles and responsibilities, and will also include new contract provisions aimed at better assessing contractor performance against a set of measurable standards. A new "Key Personnel" clause will be included, which will provide the Department with appropriate recourse over the management team at the Laboratory if it is not meeting established performance measures. Since Universities Research Association will remain the operating contractor, the position of Laboratory Director will remain a URA position. URA is currently conducting a review of the management of the laboratory, and the Department supports this review. The contract will be modified to expire in 1996, instead of 1997, so that a decision on whether to extend the contract or open it to competition can be made sooner than planned, but after a period of operation under the modified contract.

In order for the new contractual arrangement to work, clear roles, responsibilities and authorities for the Department of Energy, URA and the new Execute/Integrate contractor must be established. I envision a strong team composed of these three players, which will bring the necessary management, technical and oversight expertise to assure success. Specific delineations of lead responsibilities will be documented in a management plan to ensure smooth and effective relationships among the players during all major phases of the project, including design, construction, component development, prototyping, fabrication, installation and testing, commissioning, and, ultimately, operation. It will take some effort to work out these understandings, but we will be working these details out through the end of next month.

Clearly, the success of the project will require URA's technical and scientific involvement in all phases of the work to assure that, when complete, the facility will accomplish its planned scientific mission.

In pursuing this plan, the Department will examine options for an expedited procurement process for securing a new "Execute/Integrate" contractor. The Department of Energy will hold both contracts. This will ensure that the Department has the strong oversight and management control over its contractors that we deem necessary. This new approach assumes a larger Departmental role for management control and coordination. The Department will move promptly to establish additional technical strength necessary for executing this enhanced role.

The vast majority of current super collider laboratory employees and subcontractors will remain in their jobs and in fact are needed to ensure a smooth transition under the new organization and to continue project momentum.

I am confident that the contractual arrangements I have outlined offer a strong, viable management structure. URA is retained to do what it does best: research and development, scientific design, and management and operating of scientific facilities.

A new prime contractor is selected to bring to the project the management systems and capabilities to execute and integrate project activities.

Through these changes, I believe that the Department will bring to the SSC the combination of scientific expertise and management experience necessary for this historic project. Some will argue that implementing these changes is an acknowledgement of existing problems. It is. A more serious argument, however, would be that management problems exist and that nothing was being done to fix them. It is my view that no project as large and complex as the SSC could proceed without confronting challenges along the way. Our task at this juncture is to address those challenges in a fashion that ensures that this important project moves forward with the public confidence and support that it so rightly deserves.

This concludes my prepared testimony. I would be happy to answer your questions.

[Attachments.]

IG Recommendations and DOE Actions

Finding #1 Expenditures with Commercial Subcontractors

Recommendations

1. Require that the SSC Laboratory Director:

a. Expedite the appointment of a permanent head of the Procurement Department;

DOE Action: Complete. A permanent head has been appointed.

b. Emphasize continuity in assignments of procurement personnel so that the same buyer or subcontract administrator retains continuing responsibility for procurement actions throughout the life cycle of the subcontract;

DOE Action: Action plan will be completed by August 15,1993.

c. Establish a central point for control and oversight of contract audits;

DOE Action: Complete.

d. Implement controls to ensure that items to be purchased are needed and justified, and that items will not be purchased before they are needed;

DOE Action: In process. Action plan will be completed by August 15, 1993.

e. Provide budget distributions on a timely basis; and

DOE Action: Complete.

f. Expedite full implementation of a cost and schedule control system.

DOE Action: DOE concurs in this finding and has pressed hard to get the system in place. A review recently completed revealed a number of deficiencies which must be corrected before the system can be certified. This is expected to take an additional six months.

2. Initiate a Departmental rulemaking on the issue of what constitutes reasonable cost under contractual terms, including discretionary expenditures under any management allowance.

DOE Action: Concur with recommendation. Upon completion of rule making, the contract will be modified.

Finding #2 Expenditures with DOE Laboratories

Recommendations

1. Establish policy and procedures for procurement actions which provide for:

a. Cost/price reasonableness determinations;

b. Limiting such actions to items not obtainable form private commercial sources at less cost;

c. Fully justified actions appropriately documented;

d. Standardized agreements outlining requirements such as statements of work, breakdown structure and baseline accounting, invoicing, progress reporting, disposition of equipment and materials, and overall responsibilities;

e. Adequate equipment accountability controls;

f. Adequate fund control, to include detailed invoices, cost performance reports, and uniform accounting procedures that provide an adequate audit trail for tracking purposes; and,

g. Modifications to agreements that are fully described, justified, and documented.

DOE Action: The DOE Office of Procurement Assistance and Program Management is taking steps to establish appropriate policy and procedures.

3. DOE require that the SSC Laboratory Director:

a. Implement policy and procedures to be established for MPO's and,

b. Verify compliance with policy and procedures by conducting periodic internal audits of the MPO process.

DOE Action Upon issue of policy from the DOE Office of Procurement and Assistance the contract will be modified to reflect the new policy.

In addition

The government has been reimbursed for expenditures for Christmas card and party items.

Charges for coffee has been disallowed as of August 1992.

Flowers have been determined to be an unallowable cost.

Charges for Double-rent have been reimbursed

Excessive Bid and Proposal costs are being recovered.

SSC Laboratory Director has committed to discontinue contractor maintenance of plants.

GAO REPORT

"SUPER COLLIDER IS OVER BUDGET AND BEHIND SCHEDULE"

Major findings

The prime contractor has still not implemented a fully functioning Cost and Schedule Control System.

DOE Response: DOE concurs in this finding and has pressed hard to get the system in place. A review recently completed revealed a number of deficiencies which must be corrected before the system can be certified. This is expected to take an additional six months.

Known cost increases have offset recognized savings.

DOE Response: DOE concurs and recognizes that contingency will have to be allocated to cover the shortfall.

Cost Growth on Work in Progress

DOE Response: Aggressive action was taken to get cost growth under control. The Conventional Construction Contract has been renegotiated and is currently underrunning the new target price. Cost growth is affordable within available contingency.

DOE Following a Build-to-Cost Strategy

DOE Response: This is true for the detectors, but there are technical specifications that must be met as well as cost targets. Changes in specifications that affect to-level requirements require approval by the Deputy Secretary.

The CHAIRMAN. Thank you very much, Madam Secretary.

I see that a vote has just started. It might be a good time to break now, and I will be back immediately with other Senators.

[Recess.]

The CHAIRMAN. The hearing will resume.

Madam Secretary, thank you for an excellent statement. I am sorry we had to interrupt at least our train of thought, but I am glad we could be back quickly.

Madam Secretary, this has been perhaps the most investigated project ever. The GAO, the IG, the ICE, the Department of Energy, what have you—I think the GAO alone spent over $1 million in their investigation of this project. So to have you come in now who is the one responsible for these decisions, having the benefit of all these investigations which I know you have very carefully read, and to confirm that this project is on schedule and on budget is to me very reassuring, and I think it puts in context the proper criticisms which many of these investigations have found.

And that context to me, if I may state it and ask if you agree with it, is this: First, there were a number of things found which were true but trivial, such as spending on potted plants and parties and hotel rooms to have meetings to study the baseline and things of that sort. It is true that they spent money on those things and those things got the most attention in the press. The fact that they, gasp, were spending Federal money on liquor, as if the U.S. Senate does not do that, as if GAO itself does not do that.

It is true, and I think you already have taken steps to rearrange the management fee which I think is two-tenths of 1 percent so that that criticism, whether proper or improper will not reoccur. Nevertheless, out of a project of $8 billion, it is rather trivial to have the success or nonsuccess of this project turn on that kind of thing and to receive that kind of attention, which, after all, did not involve malfeasance or nonfeasance or taking the Government's money. It involves over broad interpretations of a contract.

Are we together so far?

Secretary O'LEARY. Well, Mr. Chairman, at the risk of not being together, let me point this out to you: I agree that the amount involved is certainly de minimis and you have described it. The danger and the harm done when the public very closely scrutinizes everything we do is immeasurable, in my view. And I want to leave this committee clear with the fact that the Department of Energy does not expend money on alcohol because we are not permitted to.

But I get the meaning of your point, but I would not want anybody hearing me today to think that I do not believe that those are inappropriate expenditures, and quite correctly, as you have pointed out, I have taken steps to see that those expenditures do not ever occur again in this project, and to the extent that I understand it I do not believe that they now occur in any other projects in the Department of Energy, either.

The CHAIRMAN. Well, I think, at the White House, for example, they spend Federal funds on having dinners and they serve wine. Big deal. The point is the laboratory was allowed to do that. It comes out of their management allowance account. I do not mean to defend the kind of accounting that took place. But i do say that in a project of this size, for that to be the headlines, the focus, the determining issue, is, it seems to me, trivial.

The second class of things in these audits I think you dealt with and dealt with very effectively in your statement, and that is the need for better management tools, better auditing tools, better predicting tools, so that as in any project of this size and complexity and dynamism—dynamism in the sense that it is a moving target because you have to design the machines you do—that we need better management tools.

As I read your statement and heard your testimony, the Department of Energy is responding to each of those suggestions made by both GAO and ICE and IG and all the rest.

Secretary O'LEARY. And all those alphabets.

The CHAIRMAN. And that is correct?

Secretary O'LEARY. Yes. And I do not mean to be flip or glib about this, because if I have any reputation, it is that I pay attention to detail and I manage well. There would be no circumstance under which I could ignore anything that I have discovered. And you can expect me to correct it and we have already begun to do that.

The CHAIRMAN. And you have confidence in the system that you are putting in operation?

Secretary O'LEARY. I will, when the system is put into place, have the highest confidence in it because I will have been very much and very intimately involved in ensuring that that system is

as failproof as one can make a system dealing with a project of this size.

The CHAIRMAN. Senator Wallop.

Senator WALLOP. Thank you, Mr. Chairman. I would agree with you that the dollar amounts in the overall scheme of things are de minimis. But I agree even more with the Secretary that because it is the headline the contractor should realize that it is not trivial. In my experience, if there is anything that the modern political mind can comprehend, it is small amounts of money spent on scandalous things. The whole program is beyond most political comprehension, and so that is why it is no longer trivial. It becomes the one thing that they cannot understand and dance around the room about. I am pleased that you have taken steps to end those things.

You stated, and I agree, that the SSC project is a marriage of world class science and world class construction that will become the focal point of the world's high energy physics program for the next century. Why, then, have we got no foreign assistance, support, contribution?

Secretary O'LEARY. Senator Wallop, my opinion is that we have not gotten as much as we project nor promised we would get for two reasons. One, most nations, most highly industrialized nations, are finding themselves in the same circumstance that we are, wondering how much we can afford with respect to investment in big science. Two, wondering when is the appropriate time to get public buy-in for projects that, as you have pointed out, people do not understand.

You know, and we have provided for the record, information that will tell you that we expect commitments for the next several fiscal years for a little under $400 million. But that does not contemplate the over $1 billion that we expect from other partners. I do not mean to be coy about it, it is the Japanese, who, quite frankly, in informal discussions say to me well, yes, we really want to collaborate with you as a financial partner, but we are also very anxious to see what your Congress will do in this budget round.

So I think that they are very carefully looking to what we will do here today and in the days following, and then I and my colleagues in this administration, hopefully along with some members of the Congress, will go out after this.

Senator WALLOP. I was wondering if it was in fact because there was some significant doubt that we had the political will to continue with the project.

Dr. Weinberg testified that any significant increase in the $8.25 billion baseline cost of the project would be attributable to stretching out the program. Do you agree with that assessment, or are there other potentially significant cost increases?

Secretary O'LEARY. Well, as I have indicated, and I cannot recall, Mr. Wallop, if you were in the room yet——

Senator WALLOP. I was not. You are kind.

Secretary O'LEARY. Let me very briefly describe to you the third part of the examination which is, in my view, the interim examination that has occurred. We asked the team that was down at the collider to really take a look at it and identify high risk elements in the project that have the potential to increase costs,

not because I thought that those high risk areas were ones that we wanted to testify about or hold onto as items which would raise the price of this project, but because in good project management you look for those high risk areas to try to reduce them or to erase them entirely.

So there will be numbers discussed and bandied about that have to do with identification of high risk areas. But I believe in proper contract management one of the things you do is you manage to reduce those costs. So I am not in the position of saying, as has been attested to earlier today, that $8.247 billion is it, with the add on for the stretch out. But I am in a position to tell you that I know where the potential is to reduce costs, and if we do not manage well I have a problem. But I expect us to manage well.

Senator WALLOP. Has there been an estimation of the additional costs resulting from replacing URA with another management contractor?

Secretary O'LEARY. Yes, indeed there has. And what we have focused on is two things. Number one, the cost of bringing on what we have identified as an integrating contract. And I will tell you that in my view it is de minimis against the project and should not amount to any more than—and I do not want to be held to this, but let me just try—maybe—I do not want to try. I do not want to try because it is not fair, because I do not know the elements of this contract.

The CHAIRMAN. You might say an amount larger than they are expecting to get.

Secretary O'LEARY. No, I do not want to say that either because I think is a little bit too cute. And I understand how to be cute, but here is the piece. The piece in my mind is we are now paying one contractor who has responsibility for the overall management for this contract. My sense is if it is managed well we can reduce costs. What I would like to do is be in a position as we go through in August and September to come back to you with a real figure that is meaningful.

I do not expect this new design to cost us money, I expect it to save us money and, more importantly, to increase the confidence in the project and what the project can and will deliver. I think that that has a value. I will give you a number by the end of September.

Senator WALLOP. But the answer is there has been an estimate made of the additional cost.

Secretary O'LEARY. There has been an estimate made of the additional cost for bringing on an integrating contractor. I understand that people have made that estimate. I am telling you that I do not at this moment—I am not certain that that is the correct estimate, and rather than have to explain it in November I would rather pull it together and give it to you in September.

Senator WALLOP. I understand and appreciate that.

Secretary O'LEARY. Thank you, sir.

Senator WALLOP. One last question, Mr. Chairman. What level of total project cost would you consider to be too great to proceed? It seems to me that one of the things that always happens to us here is that the chairman and I and others are very enthusiastic about a program, as you say, on budget or within budget, within

projected costs. Is there a moment in time when, if the projections exceed a number, that we have to take in a deep breath and say something else has to be done with this race track?

Secretary O'LEARY. Fair enough. I understand your question and I believe it is fair. And I believe it is fair of experience that we have all shared, where we have thought that an idea was too good to let go and we have seen costs creep and creep.

Senator WALLOP. We have been captured by it.

Secretary O'LEARY. Absolutely. And I think we can hold to this original baseline figure in as expended dollars, which amounts to approximately $8.25 billion. I think you have to add to it the stretch-out costs, and I think you ought to be looking at me and treating me very harshly if I am moving above that within any pale that makes sense to us.

And I would now focus myself back on the thing I know, and that is contingencies and large budgets, and I know utility construction, and normally the contingency is 10 percent. And I think you ought to hold me to that, and if you do not like 10 percent as we go forward I think you ought to hold me to something tougher than that. And I am comfortable with that. I understand that.

Senator WALLOP. I would be comfortable with that. The real concern that a lot of us have who are strong supporters is that we get so much expended that we cannot go back and it is too expensive to go forward. That is, I think, why these kinds of hearings, Mr. Chairman, are very important.

Secretary O'LEARY. Senator, I would turn my words back on you. Everything I know at this moment says on budget on time. We could do it better. We could do it cleaner, we could be better managers, but you cannot fault us for coming where we have come today. We can do it better and I want to do it better.

Senator WALLOP. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Senator Craig.

Senator CRAIG. Welcome to the committee again, Madam Secretary. It is an important issue. I want to expand beyond the thoughts of my colleague from Wyoming. I do want to associate myself with those thoughts and comments. I do not want to be captured by and find myself a few years down the road feeling caught in an "I am and therefore I must go forward" kind of argument. We have heard that too often.

When I committed myself to this big science project, and I still remain committed to it, I also said very openly and very publicly, there may come a time when I am convinced that it is no longer worthy to fund, and if it will save a billion dollars, I will pull the plug. The reason I do that is because of a $300 billion deficit.

Now, we understand with big science and big construction and pushing the edge that there has got to be some margins and there has got to be some contingency. And I am willing to do that. But I hear your words very loudly, and I believe this committee is dedicated to holding you to them.

And I know the chairman is concerned because our margins are not what they used to be, and we all know that. I would certainly hope that the chairman would continue with very progressive and continual oversight on this kind of program. It just is simply too

big not to look at on a regular basis and not to have mileposts by which we measure progress.

It is not a couple of hundred million. It is well over that, and we know it could go further than that—could go further—and we have got to stay on course.

Thank you.

Secretary O'LEARY. Thank you, Mr. Craig.

The CHAIRMAN. Senator Lott.

Senator LOTT. Thank you Mr. Chairman, and thank you Madam Secretary. I am sorry I was not here for all of your testimony. I know you surely did a very good job.

I do not want to keep you too much longer because we have another witness, but I would like to just ask a few questions. Maybe you gave this in your testimony, and I apologize if you did. But first of all, the administration and the President has absolutely committed to continuation of the super collider project, is that correct?

Secretary O'LEARY. Absolutely, we are, Mr. Lott.

Senator LOTT. And you are absolutely to not only supporting it as Secretary within the department, but aggressively trying to get the message out and the story out of what is at stake here and why we need it, what is involved, what the costs are, what the problems have been, and how you are going to solve them. You are going to do that.

Secretary O'LEARY. Absolutely. I think the record will show that I have been aggressive and I will continue to be aggressive, both in telling this story and both in assuring that we manage this project not just marginally well, but the best we know how.

Senator LOTT. How many jobs are at stake?

Secretary O'LEARY. Well, in the project itself there are roughly 2,000 jobs, but I want not to go down this primrose path with you, if you will allow me to be so bold, because my sense is, and this is certainly the case as I observed it in the other chamber of this Congress, the United States of America, is that we focused on the jobs and permitted people in other States and other areas to presume that this was about jobs today. And this project is about jobs tomorrow, and it is about the competitive position of the United States of America 20 years from today.

So I am prepared to take this walk with you and I can even share with you a map which people have tended to think shows that we have attempted to spread the value of this project and the remuneration, the short-term remuneration from this project, when in my view this indicates the very broadly flung high physics community that is involved in this project and should be used to focus on the importance of the science, so you will forgive me if I do not go this way, because I think that this is not an appropriate measure. At least it is not one that I want to make, and you will forgive me for being so blunt.

Senator LOTT. I think that is well put. Has the State of Texas fulfilled its commitments in this project, the amount of money that they have contributed to it, cooperating with the Federal Government? The State of Texas has had a substantial involvement and participation and contribution in this project, has it not?

Secretary O'LEARY. The State of Texas has been a very valuable and active partner and has, in fact, up until about 2 months ago, provided both financial support—certainly they were excellent in the early days as we began with the green field and acquiring land in support of this project.

Quite frankly, as the committee would know, of late they have gotten a little faint-hearted. It has been the glare of the press and the publicity and comments with respect to where this project is going, in my view, that has caused them to be a bit timid, but if I were to review their partnership from the day I took this job until today, I would say that they would have been excellent partners, notwithstanding their reluctance to come to the table or put it on the table over the past 6 weeks, Mr. Lott.

Senator LOTT. As I recall, at the beginning of this project when a lot of sites, a lot of States tried to be selected, one of the things we heard would happen was that there would be a substantial foreign contribution, foreign involvement. I have the impression that has not happened to the degree that we thought it would. What is the status on that?

Secretary O'LEARY. You are correct, it has not, and as I testified earlier, it certainly has not happened yet to the degree we expect it to, and earlier I had testified to my personal belief, derived at after informal conversations with some of our likely international partners, that they awaited the action of this Congress of the United States to be certain that we are serious about this project, and I am looking forward to be able to show them that we are serious about this project.

Senator LOTT. You are going to be actively looking at the management processes and auditing procedures that have been used or have not been used. Do you think that you can achieve significant controls on the costs, to rope in costs by these management and accounting procedures?

Secretary O'LEARY. I do indeed, and earlier, before you arrived, testified to the fact that part of the failing, the failing of these cost controls being in place, is this project being taken out of the normal course of review for the Department of Energy, and it needs to be returned to that course of review, and more importantly it needs a stronger partner allied with URA, and I intend to accomplish those two things.

Senator LOTT. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Lott. Madam Secretary, thank you very much. I am sorry Senator Bumpers is not here to have heard your testimony and to have an opportunity to question you about all these audits. I think any fair-minded person ought to be very reassured by what we have heard today not only about your judgment about where we are, but the steps that you are taking to put in the new audit system to control costs, to assure the taxpayers that the risks of overrun are minimized or brought to zero, or perhaps even below zero, and I hope that those around the Congress who have not heard what you have had to say will have it reported to them, and we will be quoting you extensively as this goes on.

Thank you very much for being here.

Secretary O'LEARY. Thank you, Mr. Chairman and members of the committee.

The CHAIRMAN. Our final witness is Dr. Roy F. Schwitters, who is director of the SSC in Dallas, Texas.

[Pause.]

The CHAIRMAN. Dr. Schwitters, welcome to the committee, and please proceed.

STATEMENT OF DR. ROY F. SCHWITTERS, DIRECTOR, SUPERCONDUCTING SUPER COLLIDER LABORATORY, DALLAS, TX

Dr. SCHWITTERS. Thank you very much, Mr. Chairman. It is, indeed, a pleasure to be before your committee to tell you about some of the aspects of the super collider from the perspective of the laboratory. I prepared a written testimony that I want to submit for the record.

The CHAIRMAN. That will go in the record.

Dr. SCHWITTERS. And I thought I would give an informal oral presentation of some of the points I make in that written testimony, if I might.

Senator WALLOP. Dr. Schwitters, before you testify, would you tell us about your background?

Dr. SCHWITTERS. Yes, sir. I am a physicist. I have been involved in high energy physics experimentation throughout my career. I received my doctorate in 1971 and joined the Stanford Linear Accelerator Center where I was able to participate in some wonderful series of experiments that discovered new quarks and so forth and led to a Nobel Prize for one of our colleagues.

After that, I became a teacher at Harvard and participated in research and construction of a large detector at Fermilab, so I feel very much very well supported, I must say, in my research by the Department of Energy, by this Congress, and frankly, now, I do not do too much research in my present life, but it is still a goal of mine to prepare, if you will, and give the opportunity for our young people to experience what I have been able to in my scientific career.

The CHAIRMAN. Now, you are appointed director by University Research Association, which is a consortium.

Dr. SCHWITTERS. Association.

The CHAIRMAN. Association, which is a consortium of 40 universities——

Dr. SCHWITTERS. Eighty universities.

The CHAIRMAN. Eighty universities, and you have a board of directors, do you?

Dr. SCHWITTERS. We have a board of trustees of the corporation and then the corporation also is responsible for the management oversight operations of Fermilab, so associated with each laboratory, Fermilab and SSC, there is a separate board of overseers, so my board of overseers looks in detail on the day-to-day activities of the laboratory, and then the board of trustees of the corporation looks overall at what is going on.

The CHAIRMAN. And is it safe to say that that board of overseers, as well as your board of directors, contains some of the most distinguished scientists and technology applicators, in the case of

the board of directors, such as Bob Galvin, as the country has, some Nobel laureates and others, is that correct?

Dr. SCHWITTERS. Yes, sir. Both boards have distinguished members with broad experience in science, technology, business, academia.

The CHAIRMAN. And those boards are nonpaid.

Dr. SCHWITTERS. That is correct.

The CHAIRMAN. But are active in the overseeing of the project.

Dr. SCHWITTERS. Yes, sir.

The CHAIRMAN. Please proceed.

Dr. SCHWITTERS. Thank you. I would like to start off by emphasizing again what was so eloquently put this morning, that the reason for building the super collider is to extend our knowledge of high energy physics.

As Professor Weinberg stated, it has been recognized for a generation now that a new experimental instrument was needed for us to make progress in this field. This field seeks to understand the basic principles underlying all of the physical world.

Since 1983, we have recognized that the most cost-effective and technically feasible way to address these questions is with the Superconducting Super Collider. The community proposed that to the Government in 1983, and since 1989 we have begun the project.

Now, as we stated, as you heard this morning in the beautiful presentations, the scientific goals are actually quite definite in some respects: to understand better such things as the very origin of mass, that essential element of all matter, but we also expect this machine to illuminate, so to speak, some very puzzling questions having to do with so-called dark matter, which many of our astronomer friends expect to make up 90 percent of the Universe, and yet it seems to be completely different than the stuff that you and I and everything else around us is made of.

The CHAIRMAN. And invisible to telescopes.

Dr. SCHWITTERS. That is right. Now, those are the long-range scientific goals. We do not know what will actually come out of that, what the principles will be. We do know that we will address these questions, and that is the important point.

However, necessarily, the outcome of this work and its practical application is indefinite, and its payback will occur over decades, so I cannot tell you what kind of benefits will come from that. What I can tell you is that the ideas and principles and knowledge gained by this will surely be remembered as long as there is curious life here on earth.

The ideas will far outlive the day-to-day problems that we are all wrestling with in this country today, just as we now recognize Newton, the work of Newton, Galileo, Einstein, and so on, far after the political context in which they did their pioneering work.

Nevertheless, I believe that there is immediate benefit to our country today coming about from the doing of the SSC, from the building of it, and let me try to explain, and I will do this in two different categories.

First of all, it is fair to say it is almost a cliche that necessity is the mother of invention. The very strong, scientific goals of this kind of activity bring together a group of people that simply have

to do things that have never been done before. In that process, we invent new tools and methods which then will find broader application elsewhere.

We are seeing that today, as I believe you, Mr. Chairman, mentioned, there is unprecedented scale of the use of superconducting technology that must be done in this project for it to be successful. That means that our industrial partners that are working with us have access to this technology, which is expected to be a multibillion dollar industry in the very near future, whereas just a few years ago this was a laboratory curiosity.

That gives them an opportunity to work with this, as I say, in industrial quantities, and gives them familiarity, primes the pump, so to speak, in what is going to be one very important technical area in the future.

The CHAIRMAN. Let me interrupt you at that point to say I was down at the lab with you and you showed me some things which I thought to be fascinating, and I just wish you would explain those to the committee. This may not be the purpose of building the superconductor, but I find it fascinating, anyway.

Dr. SCHWITTERS. Mr. Chairman, if you would pull up that one piece of wire, that thing that is about a centimeter wide—that I find, even though we work with this every day, I find that a minor miracle. This piece of wire will carry the current in our magnets. It carries about 7,000 amperes. That means each little strand in this wire that is built out of a bunch of strands—it looks like copper wire—each strand carries several hundred amperes.

Okay, what does that mean? Big deal. Well, I think you know that probably the largest electrical current that one normally deals with in your daily existence is the starter motor on your car, and that is carried by a wire out of a battery that is bigger than your finger that may carry 50 or 100 amperes, far less than one of these strands, and yet that wire is smaller than the wire in the electric cord to your lamp.

This wire will carry that current 24-hours-a-day, 7-days-a-week, with no heating whatsoever, no losses, with perfect efficiency. Without this miracle, you could not build these magnets.

We make enough of this cable, this 1-centimeter-wide strip, to wrap around the 48 States, and that is what I mean by taking something that was a curiosity a few years ago and making it available, forcing it through the industrial process so that we can have the quality and the quantities that we need.

The CHAIRMAN. Is that being used now?

Dr. SCHWITTERS. Yes, sir. That is being used, of course, in our magnets, and now it is available for other magnet technology—for example, in the MRI scanning technology talked about earlier—and it is considered to be a very likely potential for energy storage devices for levitating trains and the like.

But here is a case where this technology, the bridge between the laboratory and the economy, is taking place today with the developments in the collider, and there are other examples like that.

There is a second category of benefits that are immediate that I want to get into, and we also touched on that this morning, and that is the enhancement of our human resources. The doing of the

SSC has taught us a lot, taught us a lot about Government and politics and bureaucracy which I do not need to go into.

But the point is that coming together to build this challenging device—and this is people from all walks of life, scientists, engineers, secretaries, technicians, Government officials and so on—to carry out this goal makes us all better, in my view.

For example, we can use our facilities as resources for teachers. They can come in. There is a lot of exciting design engineering going on. We simply can make that available for people to show kids what is exciting and important in engineering and science.

There are other levels. We are working with major industrial companies. We are now working directly with people whose former jobs were in the defense industry. Now they are learning jobs about this kind of industry, so we are seeing in the factory place the conversion that is talked about so much of defense jobs into other kinds of technology jobs and so on.

I think the question of international participation is very important as we build teams of scientists, engineers, businessmen who must cross international boundaries to carry out this activity, so these are real, measurable benefits that are coming to our people as well as to society in the form of the return of this kind of technology.

A lot was made this morning of the possibility of using some of the facilities for cancer treatment. Let me just tell you my philosophy on that. We are, indeed, spending $8 billion of the taxpayer's money to provide this great scientific instrument. I believe, and my colleagues in the Department of Energy believe, that if there are opportunities outside high energy physics to make use of this facility with very small marginal cost, we should try to do so.

This is what happens in the case of cancer therapy. It is not a reason to build the super collider, but it simply means that there is excess capacity there.

The local and, I must say, distinguished medical school in the Dallas area expressed an interest. They supported a joint study to consider the feasibility. That was successful, so we made a very modest extension of a tunnel of a linear accelerator of a few hundred thousand dollars so at some later day the medical school, with their own financing, could come in and bring a beam out with essentially no cost to the Government or to the project, but could make use at a very modest cost of this great benefit.

Let me now turn to the progress on the project. As the Secretary of Energy mentioned, this project is now—will be by the end of this fiscal year—21 percent complete. I just show some representative photographs of some of the construction. This is a piece of land that 3 years ago was described as being so poor that you could not even raise armadillos on it, and now it has superconducting technology.

We are helping to build magnets. We are testing magnets.

We have a very large tunnel-boring machine there that is heading north, boring out parts of the tunnel underneath the ground. This is now fully occupied and a very active technical area.

In the next photograph, you see some of the tunnel itself. As of last Monday, 11.8 miles of tunnel were completed. Like beginning in any new field of endeavor, you find out the forms of competition

and record keeping and so on. We now hold, I believe, every record in the tunnel-boring-machine record book.

For example, we have four machines running underground to complete this work that has already been done. One of those drilled out that tunnel. That is about 14 feet in diameter. They went well over 400 feet in one day, well beyond the planned tunneling rate of a little over 100 feet per day. This is a consequence of some of the new technology that has been put into some of these new devices, as well as the superb quality of the underground geology.

This chart, of course, gives you the layout of the overall facility. It is dominated by the large, 54-mile tunnel underground.

Let me explain a little bit about the colors. The dark blue-green color represents that part of the tunnel that is under contract, and the red color is that part of the tunnel that has already been completed, so you can see that is the 11.8 miles that have been completed.

There are other green areas that represent places on the surface where there has been significant construction activity.

The CHAIRMAN. Your tunneling cost, is that coming in on projection?

Dr. SCHWITTERS. Sir, they are coming in below projection; roughly 21 percent below projections.

The CHAIRMAN. And the tunneling involves roughly what percentage of the total project?

Dr. SCHWITTERS. The overall civil construction budget is about $1.25 billion. The tunneling, I think, is about a third of that. But the important thing is that, that entire civil construction, which involves the technical buildings we showed you, the shafts down to the tunnel, and the tunnel itself, is projecting to come out slightly under its projected amount.

I should just say, that tunnel, by the way, goes under existing homes and farms and so on. The large yellow areas, the so-called east and west complexes, are the principal areas where we retain the full control of the surface. But the collider is benign, from an environmental point of view, so the tunnel simply goes underground, under the existing farms, roads, and towns.

The State of Texas gained easements, so that people did not drill oil wells through the tunnel or something. We have tried to avoid that.

Now, in addition to the civil construction, we met a very important technical milestone last August, 6 weeks ahead of schedule. There was a so-called string test, to test the basic concepts of the superconducting magnets produced by industry, that would be needed for the collider. This was a complete success. And I think the significance of that is that the most important technical component shown here the superconducting magnets, they simply look like those red tubes from the outside, are being engineered and built, we believe, with quite satisfactory performance.

The CHAIRMAN. Now, Dr. Schwitters——

Dr. SCHWITTERS. Yes?

The CHAIRMAN. Steve Weinberg testified this morning about the redesign of that, and the fact that that was responsible for perhaps a third of the increase, that big increase of cost from 5.9 to 8.2.

Dr. SCHWITTERS. 8.2, that is correct.

The CHAIRMAN. Now that you have the string test complete, is this not one of the most important deal-breaker questions about the cost of the project?

Dr. SCHWITTERS. Yes, sir. Yes, sir. Precisely. I am focusing here on the civil construction and the magnets. Those two are the biggest cost items in the project; and that is precisely why they have received so much attention.

We are now taking this technology for these magnets, which was only available in the laboratories before this began, and transferring this into industry. And that is why it has received so much attention: Because of the cost issue; as well as the basic technical feasibility. On both issues, we are seeing highly satisfactory results.

In addition to the magnet work, let me just pass over a few other milestones. We have actually accelerated now the first beam of protons to 2.5 million volts. That required the first 6 feet or so of the accelerator. It is working quite satisfactorily. It also pushes the state of art of low-energy accelerators. This was built in collaboration with other laboratories and industry, and is fully meeting our design specs. We hope to begin installing this linear accelerator, as it is called, the first part of the injector machines, later this year into its tunnel, which is now complete and waiting for it.

On the scientific front, I can report to you that two very talented collaborations of scientists, involving over 2,000 scientists worldwide, have now proposed to us detectors, to carry out the scientific program, that will fully meet the challenges of the SSC. So this already represents a major international effort in the scientific program, with approximately half the scientists participating in this coming from foreign institutions that represent 23 different countries.

Let me now turn to say a few more words about this cost and schedule issue. I completely support the Secretary's statement earlier, that this project is meeting the goals presented to the Congress in the 1991 report; that it has a total project cost of $8.249 billion. That has been a very important management goal of ours.

We, of course, have had funding that has not come in at the same rate as projected in that report. In the past 2 years, the funding has been somewhat slower than that; and therefore, some of the initial work has been postponed. But the long poles in the tent, the magnet production, the tunneling, and so forth, are on a very satisfactory course. We certainly hope that we can get back to a construction profile, a funding profile, that is similar to what was presented in that earlier report to the Congress by DOE.

But the most important thing is, I think, stated here in different ways, is that that basic plan is solid. There are risks; and I will come to that in a minute. And that the value that has actually been, of the work accomplished, is meeting our objectives. The Secretary said that, and I want to emphasize that. That is a very important outcome of these recent reviews, that this estimated value of 21 percent complete, that I gave you, has been accepted by all of the reviewers looking at this work. And I have tried to

give you a sense of it by these photographs. But, of course, there is much more detailed information on that.

So here we are today, with essentially one-fifth of the project complete; and with, essentially, one-fifth of the funds expended. And I think that is a simple-minded view, a way to look at this basic question of management and cost performance.

Of course, the President did suggest a stretchout in his message earlier this year. We are in the process of examining that, along with the other technical risks that have been mentioned. We focused on the magnets and the tunneling, and so forth; and now, the attention of the designers and managers and engineers is going on these other areas. I think that the Secretary explained this very well, that those are areas where preliminary estimates have been made by some of the designers, and so forth. We have to examine them from a management point of view, from a priority point of view. My judgment is that that can be done on a basis that will minimize the contingencies that you talked about before. I think the Secretary's comments were right on the mark on that, and I support them.

Now, let me come to some of the questions about management, and I am sure you will have many more. Of course, there have been many critical reports that have been discussed here earlier, throughout this testimony. I would characterize the general theme of those reports that deal with the large project management questions as relating to, if you will, the transparency of audit and management information to the Department of Energy and to the reviewers.

On this, I agree. We need to improve the transparency of this information. There is no contention on that point. We are certainly concerned about that in our own shop, and support the Secretary's comments on that to you just a few minutes ago. No question about that. In all of the reports, all of the activities going on, I should say, there has been a record of consultation, oversight, agreement with the Department of Energy in these key areas. And we feel that is very important for our own work for the future.

I will just give two examples, I think, of some of the more spectacular claims that I would like to at least explain where they stand today. I think they have been discussed earlier.

First of all, the GAO's report in February looked at construction data from a year ago this month, and projected a $632 million overrun in construction. As you, Sir, yourself reported earlier, if one looks at the data now in the fullness of time and with more experience, we are projecting a $40 million underrun on that work.

The second largest financial claim made in these reports was that of $156 million that was spent at our National laboratories through what is called memorandum purchase orders. This work, I should point out, was the crucial superconducting work, where the only place in this country one can gain access to this technology was at our National laboratories.

The Department had a very streamlined procedure to allow us to define that work and transfer funds, and attach them to the other laboratory. That had the great benefit of expediting the work, and was materially responsible, in my view, for the excellent performance on the magnet development, development program,

where the industrial contractors could call into our National labs, gain the technology, and take them back to their laboratories.

Finally, let me just state an experience I participated in, along with the Secretary of Energy, a number of her top staff, and the other laboratory directors. And that was a visit to what is called Motorola University, where we were all immersed in these new ideas of total quality management.

I very strongly endorse the Secretary's initiative in that area. I think we can use it to improve our efficiency of operations on oversight, as well as management. And I happen to agree with her contention that the situation is not bleak at all, in terms of costs. I think the key is to improve efficiency of the oversight, of all the business practices, and so forth, that we have to go through.

Let me describe briefly to you the current situation at the laboratory. As you know, of course, very well, this is the second year in a row that the House has voted to remove funding from the collider. This, needless to say, has had a very negative effect on personnel and their morale at the laboratory.

We have a great staff of dedicated people, who have literally come from all over the world. They are a young, exciting staff, who have bet their scientific careers on this program. And, of course, there is great concern about their future, and the future of this science.

Furthermore, to meet our contractual obligations this fiscal year, under any of the scenarios from Congress, we will have to take extreme austerity measures this summer. So we have, essentially, halted all discretionary funding work, and so on. Finally, there has been a very large number of reviews. These committees, that come to visit us and give the various reports that you hear, also impact the work going on. So I think for all of these reasons, there is no question that these are difficult times for the staff.

I am very encouraged by the hearing here today. I am certainly going to report back to our staff on all that we have heard today. I think this has been very positive, and I look forward to taking it back to them; and I am sure that is going to help a lot.

Let me just close by saying I urge, I really appreciate and urge your continuing support for this program. I think it is crucial for this country to remain on the cutting edge of this intellectually exciting and historically important area of physics, of science, that simply cannot be done without this kind of investment in the future.

I think we also must be able to demonstrate to ourselves and our colleagues around the world that we have the wherewithal to complete these very important projects that we begin. Thank you very much.

[The prepared statement of Dr. Schwitters follows:]

PREPARED STATEMENT OF DR. ROY F. SCHWITTERS, DIRECTOR, SUPERCONDUCTING SUPER COLLIDER LABORATORY, DALLAS, TX

I am pleased to have the opportunity to discuss with you a number of aspects of the Superconducting Super Collider. First, I would like to make some brief remarks about the need for the SSC and about the impressive progress that has been made on the SSC in the past year. Then, I will turn to some comments about a series of charges and allegations that have been made about management of the SSC. I have submitted to the Committee and Subcommittee staff a set of much more detailed discussions of the issues involved.

For well over a decade, the scientific community has recognized the need for a major new experimental facility to advance high energy physics, the area of science that seeks to understand the fundamental principles underlying the structure and interactions of everything in the physical universe. The SSC, proposed in 1983, is the most cost effective and technically feasible way to achieve this scientific imperative. It will provide crucial new information on some of the deepest mysteries in nature such as the origin of mass, that most essential property of all matter, and the nature of the dark matter that appears to make up 90% of the mass of the universe, yet seems to be of a completely different character than the stuff you and I and our world are made of. We don't know precisely what will be discovered at the SSC because we will be exploring in a new physical domain, but if history is any guide, we do know that the knowledge gained will benefit all humankind and that its impact on society will develop over decades. The SSC will be our contribution to culture of the twenty-first century.

On the immediate time scale, the "doing" of the SSC benefits us today. Meeting the challenges of building and operating the SSC has already had an impact and will continue to benefit the nation in two general ways. First, new tools and methods must be invented to achieve SSC performance requirements and many of these find significant application in broad areas of science and technology. Examples include the large-scale industrialization of superconducting technology for SSC magnets, the use of proton beams in cancer therapy, high-performance parallel computing for SSC physics analysis, advanced tunnel boring machines with applications in construction of large water-projects and rapid transit systems, and advances in broadly-used technologies such as cryogenics, electronics, particle detection, and communications. A second general category of immediate benefits is the advancement of human resources at all levels ranging from such things as exciting the imagination of young people to pursue science and math in school, conversion of defense jobs into new areas of advanced technology, high standards of scientific and technical training for students engaged in SSC-related research many of whom go on to careers in industry and government, formation of new teams of scientists and industrialists, and the establishment of new international working relationships for industries and scientific institutes. A key point is that the clear and exciting scientific goals of the SSC draw exceptionally talented people to build and use this facility and they, in turn, make the SSC a kind of crucible within which human potential expands and new tools, methods, and ideas are formed. In my view, these benefits directly contribute to our nation's standing in the highly competitive world around us and, thus, fully justify the cost of completing the SSC.

Four years into the SSC project, we know with great confidence that the SSC can be built and it is, in fact, being built. By the end of September, 1993, $1.7 B will have been spent on the SSC project and 21% of SSC's construction work will be complete. The critical superconducting dipole magnets passed a major development milestone in August, 1992, six weeks ahead of schedule. The technology that has enabled us to meet what was once viewed—correctly—as our most significant technological challenge has been successfully transferred to industry from our high energy physics laboratories. Industry is now developing the methods to produce the magnets in the large quantities needed for the SSC. Over eleven miles of the 54-mile collider tunnel have been completed, and seventy percent of the tunnel is under contract. The housing for the linear accelerator is ready for installation. Protons have been successfully accelerated to 2.5 MeV in the Radio-Frequency Quadrupole. Two international collaborations, involving nearly 2000 scientists from 23 countries, have designed huge and sophisticated detectors that will address the scientific questions of the SSC.

Our experience to date with technical progress and with financial and schedule performance allows us to say with confidence that, if funds were allocated according to the schedule projected in the 1991 DOE report to the Congress, the SSC could be completed by 1999 within the $8.249 billion estimate of total project cost. The President has announced the intention of the administration to stretch-out the SSC by three years, lowering expenditures for the next several years and increasing the overall cost, principally due to the effects of inflation and inefficiencies in production of components. We are currently doing a careful analysis of how we can accommodate the stretch-out with the smallest possible effect on total cost.

While there is essentially universal agreement on the scientific merits of the SSC and on the technical accomplishments of the SSC Laboratory team, this year has seen considerable discussion, much of it critical, of SSC management. The SSC is perhaps the most reviewed construction project in history. The Department of Energy onsite staff and additional reviewers from GAO, IG, congressional staff, and contractors and consultants to these agencies usually number over a hundred on site at the SSC at any given time. Their reviews have raised concerns, some—but

not all—of which are shared by SSC Laboratory management, about the quality and timeliness of some financial information, the accuracy of cost estimates, the adequacy of some of the management procedures employed, as well as about the appropriateness of some relatively small discretionary expenditures. In all areas of concern, it should be noted that there has been a record of consultation with DOE officials and it must be emphasized that no actions have been taken by the Laboratory without first having obtained appropriate approvals from the DOE.

Let me address some specific topics that have been cited in the critical reports:

Project Management Control System: URA's contract with the Department of Energy requires that we put in place an automated project management control system (PMCS). Integrating an enormous amount of financial, budgetary, and schedule information, such a system allows an efficient means of measuring the project's progress and provides a tool for projecting its future expenditure trends. URA understands the importance of the PMCS and has been working diligently to obtain final DOE approval of a system that it has had in place and operating since October 1992.

This is a little more than a year behind our original projections, which would have resulted in a completed system in October 1991 and final DOE validation in the spring and summer of 1992. I would like to explain the reason for the delay.

In the spring of 1991, some nine months before we hoped to have implemented the PMCS, it became clear to us that the management control system we were working on, while adequate for handling the then-current project activities, was likely to prove inadequate for tracking the many elements of a project of this magnitude over the long term. With DOE's concurrence, we decided to begin work on a substantially different system that would better satisfy the project's future demands. Once this system was developed in the winter of 1991-1992, we waited for the beginning of the next fiscal year to begin its implementation in order to avoid the difficulties and potential inaccuracies that would have been associated with changing systems in midyear.

It is important to recognize, however, that at no time during the project were we unable to obtain and provide accurate cost and schedule information. It is true that the new system is more efficient for doing this, but until October 1992 the old system yielded perfectly adequate information for the managers of the project. (Allow me to note that one clear indicator of the fact that our managers have always possessed effective management information systems is the clear and widely acknowledged technical progress of the SSC. Had effective systems not been in place, we would not have reached the current advanced stage of the project with so much success.)

We are currently working with DOE to obtain final validation of the new system. DOE's reviewers agree with us that the system is functional, but they point out a number of what they characterize as typical start-up problems, problems that we are working to correct. We are hopeful that the process of ironing out the kinks in the system will be completed by early fall.

Connected to the issues surrounding the PMCS have been concerns about a so-called "negative management reserve" in the Laboratory's budgeting process. The very term "negative management reserve" conjures up visions of misallocation of funds, but it is nothing of the sort. In fact, what has been characterized as "negative management reserve" is an accurate accounting of tasks not clearly included in the project's baseline cost estimate but that project managers currently feel will represent necessary expenditures to assure the success of the project. When the time comes to incur these expenditures, we will have to find appropriate sources of funds to pay for them without increasing the overall project cost. We may be able to obtain savings in other parts of the project that will make funds available for some of these actions; we may have to draw upon the contingency that is already included in the estimated total project cost; or we may have to reduce the scope of other parts of the project. The term "negative management reserve" is an unfortunate one, but the principle of itemizing potential future expenditures that will have to be accounted for is not.

Expenditures at Other National Laboratories: The Inspector General has questioned $156M in expenditures at other national laboratories in support of the SSC. The IG's report stated that the SSC Laboratory did not select the laboratories on a competitive basis and that this resulted in inadequate control and accountability for funds and equipment. It should be understood that it was the pioneering work on superconducting magnet technology at Fermilab, Brookhaven National Laboratory, and Lawrence Berkeley Laboratory that made possible the very existence of the SSC. The national laboratories were the only places in the United States that possessed both the experience and the facilities to carry out the first stages of the SSC's superconducting magnet development program which

involved the transfer of technology, first to the SSC Laboratory and then to the Laboratory's two industrial contractors—General Dynamics and Westinghouse. The initial stages of the SSC's magnet program that are under criticism by the IG resulted in a resounding success when measured by any of the stated objectives of the government and the SSC Laboratory. The technology was successfully transferred to the staffs of the two companies and they successfully produced magnets—ahead of schedule, with performance exceeding expectations and within the budget line provided by the Laboratory. These magnets were used to complete the SSC's string test, which demonstrated beyond a doubt that the fundamental technical questions concerning the magnets had been resolved.

Yet the IG report attacked the administrative process used in achieving this success story, a process that was reviewed and authorized by DOE. We recognize that the IG recommends that better documentation accompany such transactions in the future, and in this we are fully prepared to comply.

Discretionary funds: Under the terms of its contract with DOE, Universities Research Association (URA) negotiates, each year, a management allowance established for the explicit purpose of covering business costs that would otherwise not be allowable under the contract. The management allowance is needed because URA receives no fee and no profit for its role in managing and operating the SSC. The management allowance this year is about 0.2% of SSC funding and part of it (approximately $30/employee) helps to support Employee Recreation Association activities, such as the family picnic and traditional holiday activities as well as the maintenance of plants in the converted warehouses that serve as our modest office space. These are normal business expenses that are fully audited and their incurrence follows prudent practices established at other laboratories, in private business, and in government workplaces. However, I believe the SSC is being held to higher standards than have been applied in the past; URA will welcome new guidance from the Congress and DOE to insure that future use of discretionary funds is beyond reproach.

URA believes that management changes are needed to respond to deficiencies, both real and perceived, and that these changes can be made in a manner that will strengthen the overall SSC effort with a minimum of disruption. I recently attended a seminar on quality management at Motorola University with the top leadership of DOE and the directors of other national laboratories. I am convinced that there are new quality management techniques that can and should be used at the SSC to improve our overall efficiency and performance, and I enthusiastically endorse the Secretary of Energy's initiative in this area.

We at the SSC Laboratory are deeply disturbed by the allegations of management deficiencies; even in those instances in which it can be demonstrated that the allegations have no basis in fact, the Laboratory and its work are damaged by the perception that there have been problems. We are thus committed to making substantive changes and will work closely with the Department of Energy to insure that these changes improve both the conduct and the image of the SSC project.

The vote in the House of Representatives earlier this summer to eliminate funding for the super collider is a matter of great concern both at the Laboratory and throughout the world high energy physics community. In my view, the SSC is of enormous value to our nation because of its scientific and technical promise and because of the importance to ourselves and to our standing abroad in demonstrating our commitment to successfully complete the challenging technological programs that we undertake.

Just as it did last year, the fate of the Superconducting Super Collider, and with it the continuation of America's leadership in humanity's ages-old quest for a better and deeper understanding of the world around us, now rests with the Senate. Last year, the Senate recognized the importance of the SSC and voted to restore funding. Today, if anything the scientific case for the SSC is stronger, the outstanding technical challenges have been met, and we are actually building it. I hope the Senate will recognize this and reaffirm its support of the SSC.

The CHAIRMAN. Thank you very much, Dr. Schwitters, for an excellent presentation. Just a couple of questions.

First of all, the $8.249 billion, which is the current estimate, is in as-spent dollars; some of those dollars not to be spent until the latter half of this decade—in fact, most of the dollars not to be spent until the latter half of this decade. If you put that in 1993 dollars, how much would that be?

Dr. SCHWITTERS. It is about $7.3 billion.

The CHAIRMAN. $7.3 billion?

Dr. SCHWITTERS. Yes, sir.

The CHAIRMAN. And you have already invested about $2 billion?

Dr. SCHWITTERS. That is correct.

The CHAIRMAN. And there are other—before we go to the floor with this, I will get a figure from you. I already have one from you, but that the Secretary will have to sign onto on the termination costs.

Dr. SCHWITTERS. Yes.

The CHAIRMAN. Because I think it is important for everybody to know, first, that these figures which I have thrown around—$20 billion, $12 billion, whatever it is—first of all, those are imaginary numbers.

Secondly, if you bring the number down to 1993 dollars, which is what we talk about in any project here, it is $7.3 billion; of which 2 has been spent. And termination expenses are a great deal more. So the savings to the taxpayer, while still a multibillion dollar amount, is far, far less than anything we have been talking about; and, as a percentage of the deficit or a percentage of the budget, it is very small: forty-three one thousandth of 1 percent of the budget this year. And, if you put it over the life cycle of the project, I think it is even less than that.

So it is highly symbolic. It is symbolic as to what we would do to science, on the negative side; and only symbolic as to what we do to the deficit, on the positive side.

And I hope, and I expect, frankly, that when we come back in September and consider this matter in the cool light of day, bereft of the emotion, doing away with the incorrect facts, bringing the criticisms and the corrective actions in their proper context, and with the benefit of the scientific and technological testimony we have heard today, I think, and frankly I expect, that the Congress will see this matter differently. That the House will; the Senate always has supported this, and I would expect that they will again.

It is simply that the termination of this project, in my view, is just unthinkable. Absolutely unthinkable, when you consider how far into it we are; how successful it has been; how, really the unknown matters here such as the magnets, have been successfully conquered. The tunneling, which is 54 miles of tunneling, has not only been done successfully, but breaking records, under cost.

Which is not to say that the remaining challenges are not great. Which is not to say that the dangers of cost overruns, identified by the Secretary, for which corrective actions are in the process, have been or are in the process of being done, are not minor matters. They are.

But as she said, and as you and others have said, there is a high degree of confidence that this project will not only be done on budget, on time, but that it will be incredibly successful, to determine that basic knowledge, that basic science about who we are, what we are made of, what the universe is about; that all intelligent human beings, I would think, ought to be very curious about. So I am curious about what our vote count is going to be in September, and I am also very optimistic about it.

We have a 15-minute roll call vote. Senator Mathews, have you voted?

Senator MATHEWS. I have.

The CHAIRMAN. Well, let me turn the questioning over to you, and let me go vote. That is all the questions I have, Dr. Schwitters. So, when Senator Mathews has finished, then you are free, with thanks.

Thanks to all the witnesses today. I think this has been an excellent hearing, and I only wish that every member of Congress could have heard what has gone on here today. I think it would be very persuasive and very reassuring. So thank you very much.

Dr. SCHWITTERS. Thank you.

The CHAIRMAN. Thank you, Senator.

Senator MATHEWS [presiding]. Thank you, Senator.

Dr. Schwitters, I guess one of the handicaps under which we suffer or work, labor, whatever you want to say, here in the Congress, is the fact that we have competing activities here which deny some of us the opportunity to have participated in all that is going on here today. We have been in every type of meeting, I guess, imaginable. I had three committee meetings at the same time this morning. But I chose to attend the afternoon session here, and then we have been voting, and health care.

I do not know that I have any particular questions I would like to ask. I would like to make a couple of comments and then ask you, if you would, to comment.

As you may know, my State of Tennessee was one that made a tremendous bid. We made the short list in terms of competing for this project.

Dr. SCHWITTERS. You sure did.

Senator MATHEWS. And the successful State, as did the others, went to a considerable expense to try to participate in this. And I am sure that the State of Texas has put a considerable investment in this program.

I guess what I would like to reflect on for just a second is the thing that we are debating on the floor of the Senate right now—this flood bill, disaster relief. And we are talking about spending up to, I guess the highest figure I saw on that and I do not whether it will go to that length or not, but something like $8 billion to let the people in the Midwest put their lives back together again and cities be rebuilt and the infrastructure be replaced. And we are going to be asked to vote before the week is over on a trillion and a half dollar budget—is that the figure I remember—and to raise $55 billion in new taxes.

Yesterday alone I got over 700 phone calls saying, do not do this to us. Our problem is not that we are spending too little or taxing too little, it is that we are spending too much. So, we are facing a lot of competing demands for money and time and so forth. I say all of this to say, you know, at some point we have got to get our priorities in order.

How essential is it that this project proceed at this time versus at a time when the economy might be a little better to us?

Dr. SCHWITTERS. I would be glad to address that. And if I might, just with your opening remark, let me say that in my prior life before this one I was a member of a National Academy panel that searched, read all of the State proposals, Tennessee's included, and came up with the short list. I was tremendously impressed by that.

There were proposals—I think there were 43 from 25 States, I have forgotten the exact number, all of them with such optimism about the benefits of doing this kind of activity, the benefits to education, to technology around the country, to improving ourselves. There was such enthusiasm and excitement in every one of those.

Tennessee has not been a major player in high energy physics and yet your State, I can say, had a superb proposal. And being on the short list it meant in my mind as I read it that that was as good as any. You could build a viable and productive laboratory there. In the end Texas won it. They also had an excellent proposal, and they have come through with the funding and the other things we have heard about.

Now, let me get on directly to your question of why do we need to do it now. This instrument has been viewed, as I said in my remarks earlier, as an essential next step to continue the field of high energy physics in this country from a leadership position.

We have recognized for a generation now that new experimental instruments would be needed to make progress in this field, and we have recognized for the past decade that this is the best way to do it, the most cost effective way to answer the scientific questions that are in front of us, and to give us the window on the future hopefully of new discoveries that we cannot even anticipate today.

So in that sense, within our community there have been very tough priorities set for the past decade about this being the focus within high energy physics. When you go beyond that then, of course, that is what you get paid for and these are very difficult choices.

Physics, like any human endeavor, is done by people. It is done by dedicated people and is done in a way that is really intimate work with students, training, through professors, through research supervisors and so on, and the work can only be done with talented, dedicated people.

My concern, sir, is that if you stop this today and we wait for better economic times that you simply stop that flow of people, those critical people, the bright young people that are going to be making the discoveries. In fact we have many kids in grade school who come to our lab who will just be in college and in the research work when this machine comes on line.

So, the real answer to your question is we will stop that flow of people. And then the question is when will you ever pick it up, and I just do not know. I am an optimist, I am not an alarmist, just in my own personal outlook. But we have a young Russian scientist who left what was then the Soviet Union, went to work in Europe, and he brought his family over to Ouxahatchee, Texas, on the promise of this great machine. He had very good job in Europe, but this was so exciting and so important to him, he wanted to be at the frontier.

He was interviewed by the local newspapers because the trauma, if you will, over uncertainty among many of the staff. And he answered that question. He said the last time that Western society really took an about-turn on being on the cutting edge of science we had the Middle Ages.

Now, that is a little extreme but I think in this field of cutting edge physics on the forefront of knowledge of the principles underlying the physical universe as we know it, this would represent the stopping of that preeminent position of this country, and it would take decades in my view to regain that.

Senator MATHEWS. In our State, and again you could relate to this and tell the story much better than I can, but back in the forties some strange things were happening in the hill country right outside of Knoxville there that very few of us knew what was going on until it was almost over, I guess. And I am referring to Oak Ridge and to the building of the atomic bomb that took place there.

And if any of us had any doubt about what science could offer to us, notice the developments that have come along since then. That lab, and I hope that the Secretary referred to it this afternoon in her testimony, is under her jurisdiction now, Oak Ridge National Lab, and it is one of the premier labs in the country.

Dr. SCHWITTERS. Yes, sir.

Senator MATHEWS. And I say a lot of this to say that I guess we have a real appreciation for the work that you are doing there with the super collider and others. What the end result is going to be, it will be probably 3 or 4 days before any of us know, but a lot of us are going through some of these tough choices and alternatives.

But I want to commend you for the leadership that you have given to this and the work that you have done. And I want you to know that if it is not possible to go now, Mathews is one member of the committee that will be working to see that it does come about at some point.

Dr. SCHWITTERS. Thank you very much.

Senator MATHEWS. Is there any further statement from anyone?

[No response.]

Senator MATHEWS. We stand in adjournment. Thank you.

[Whereupon, at 4:08 p.m., the hearing was adjourned.]

APPENDIXES

APPENDIX I

Responses to Additional Questions

SUPERCONDUCTING SUPER COLLIDER,
OFFICE OF THE DIRECTOR,
Dallas, TX, August 19, 1993.

Hon. J. BENNETT JOHNSTON,
U.S. Senate, Committee on Energy and Natural Resources, Washington, DC.

DEAR CHAIRMAN JOHNSTON: In response to your letter of August 9, enclosed are the responses prepared to address the supplementary questions for the record posed by Senator Wellstone.

If you need further information, please feel free to call me.

Sincerely,

ROY F. SCHWITTERS.

[Enclosure.]

RESPONSES TO QUESTIONS FROM SENATOR WELLSTONE

Question 1. Please describe, in the greatest scientific detail possible, any problem that exists currently or once existed with achieving the desired vacuum in the SSC.

Answer. A high vacuum is required in the Collider beam tube (inside diameter ≅ 40mm, circumference = 87. 1km) because the circulating 20TeV protons will have nuclear interactions with any gas molecules that are present. These interactions have two undesirable effects: (1) the 20TeV protons are lost from the circulating beam and (2) showers of nuclear reaction products carry the energy of the lost protons into the low temperature 4.20°K magnet cryostats. The first effect leads to a decrease in beam lifetime which depends on the average gas density around the entire 87.1km circumference of the Collider. The second effect causes the temperature in the cryostats to increase and can lead to an unstable increase of beam tube pressure and/or a magnet quench if the power deposited is high enough. Since the nuclear reaction products from a beam gas interaction are deposited within a ~40m downstream region, an unstable increase of beam tube pressure and/or a magnet quench depends on the local gas density and can occur even though the magnitude of the local gas density bump does not contribute significantly to degradation of the beam lifetime. If the beam lifetime becomes unacceptably short or an unstable local increase of beam tube pressure and/or a quench of the superconducting magnets occurs, then it becomes necessary to stop operation of the Collider and improve the vacuum conditions. This can only be done by warming up the cold bore tube and pumping out the cryosorbed gases. Since this would take time away from doing useful physics it is desirable to keep the number of cold bore warm ups to a minimum.

The allowable average gas density is determined by the beam lifetime requirement. For vacuum design this has been taken to be 300 hrs, roughly an order of magnitude greater than the beam lifetime due to beam-beam collisions in the interaction regions.[1] The gases normally present in an ultra-high vacuum system beam tube environment are H_2, CH_4, CO and CO_2. Taken individually, the 300 hrs beam lifetime corresponds to average gas densities $3x10^8 H_2/cm^3$ or $7x10^7 CO/cm^3$.

The maximum local gas density that can be allowed in the beam tube is determined by the maximum power density 0.6W/m that can be deposited in the cryostats.[2] Again taken individually, the corresponding gas densities are $4x10^{10} H_2/cm^3$ and $7x10^9 CO/cm^3$.

Whenever a charged particle is accelerated, for example by bending its orbit with a dipole magnetic field, the particle radiates photons. The radiation produced by a charged particle orbiting in a circular accelerator is called synchrotron radiation. The issue in achieving the desired vacuum conditions in the Collider is due to the combination of synchrotron radiation produced by the circulating protons with the 4.20°K bore tube of the superconducting magnets. In the Collider at design beam current .072A, the synchrotron radiation is characterized by intensity $1x10^{16}$ photons/m/sec, critical energy 284eV and radiated power 0.140W/m (9kW/ring). The synchrotron radiation photons are absorbed on the beam tube wall where they can readily desorb gas molecules which contribute to the gas density in the beam tube. The gas then accumulates by cryosorption on the beam tube wall. Although the cryosorption or pumping of gases on the beam tube wall initially has the beneficial effect of removing the gas from the beam tube volume, there are two detrimental effects that increase over time. Firstly, the cryosorbed gases themselves become a source of gas that can be desorbed by the synchrotron radiation. Since the cryosorbed gases are ~100 times more weakly bound than the original chemisorbed molecules the desorption coefficients (molecules released per incident photon) can become quite large. Second, as the surface density of cryosorbed molecules builds up the equilibrium vapor density due to their thermal evaporation increases, eventually reaching the saturation vapor density when the surface density reaches and exceeds one monolayer. For H_2 at 4.2°K the saturation vapor density is $2x10^{12}H_2/cm^3$ which exceeds the maximum allowable local density ($4x10^{10}H_2/cm^3$) by a factor of 50. For the other gases that are important (CH_4, CO and CO_2) the equilibrium vapor densities at 4.2°K are quite negligible. The time to accumulate one monolayer of H_2 therefore is an upper bound on the time interval between beam tube warm ups. Degradation of beam lifetime due to photodesorption of cryosorbed molecules could decrease this interval. At the present time there does not exist for any candidate beam tube material or configuration an adequate data base and scientific understanding of 4.2°K beam tube desorption to allow definite prediction of the number of beam tube warm ups that may be required in one year of Collider operation. Existing data and models cannot rule out the possibility that something in the range of one warm up every one to two weeks of operation may be required. This would cause an unacceptable operational burden and the goal is therefore to identify a procedure that would bring this warm up interval into the range of once per year.

A straightforward resolution to the vacuum issue that would meet the availability goal is to install a perforated liner inside the bore tube. The photodesorbed gases would be pumped through the perforations and cryosorbed behind the liner, out of the view of the synchrotron radiation. However installing a liner entails some increase in cost (see the answer to question (5) below) and the present position is to implement the liner only if it seems necessary for operational availability. The liner concepts are being developed as insertable devices into as built magnets and spool pieces so that, if needed, they can be available as a "backup". Installation of the liner would not cause a delay in Collider operation. The liner approach is being taken by the CERN LHC.[3] However the primary motivation for taking this route in LHC is not vacuum but interception of the synchrotron radiation power at a temperature higher (~10 to 20°K) than the 1.8°K temperature of the LHC magnet cryostats. In the case of LHC the added cost of the liner is more than offset by the savings in refrigeration cost. For SSC however, with a higher temperature 4.2°K cryostat, it is economically feasible to intercept the synchrotron power on the magnet bore tube.

The SSC and the LHC are the first proton colliders where synchrotron radiation is an important factor because of the fourth power scaling of synchrotron radiation power with the ratio of beam energy to rest mass. For example at the FNAL Tevatron with beam energy approximately 1TeV, the synchrotron radiation intensity is $\sim 4x10^{14}$photons/m/sec, the critical energy is 0.5eV and the radiated power density is 10^{-5}W/m. Photodesorption and power densities at this level are quite negligible. Of course electron colliders and storage rings, because of the lower electron rest mass, have dealt with the synchrotron radiation problem for many years. However because of the lower electron momentum the magnetic fields are much weaker so normal conducting magnets with large aperture and access to the beam tube can be used. This allows distributed NEG and ion pumping to be used to remove the gas from the beam tube. The space required by these systems would not be an economical solution to the problem in the SSC.

Question 2. Please describe in detail the participants, dates, and locations of any meetings of SSC scientists and/or other scientists to discuss the vacuum problem referred to in question (1) above.

Answer. Since April 1991 there have been five meetings devoted to the vacuum problems encountered in the next generation of proton colliders. The date, location and number of participants at each of these meetings is given in Table 1 below. Complete lists of names of participants and their institutions are given in the Appendix.

Table 1.—SUMMARY OF PROTON COLLIDER VACUUM MEETINGS SINCE APRIL 1991

Location	Date	No. of participants
SSCL	April 10, 1991	24
CERN	May 2-3, 1991	35
SSCL	Nov. 13, 1992	40
SSCL	Mar. 31, 1993	~22
SSCL	May 24-25, 1993	78

Question 3. In as much scientific detail as possible, please describe the problems addressed, theories proposed, and resolutions considered at the meetings described in your response to question (2) above.

Answer. The problems, theories and resolutions discussed in connection with the Collider vacuum issues cover a lot of ground which can be divided into the following six categories that will be discussed below: (a) simulation and measurement of the 4.2°K beam tube vacuum, (b) modeling of the 4.2°K beam tube vacuum, (c) the origin of photodesorbed gases, (d) beam tube materials options, and (e) beam tube pre-treatment (f) liner and distributed pump options.

(a) Simulation and measurement of the 4.2°K beam tube vacuum.

The issue being dealt with here and in 3.(b) below is obtaining information that will allow prediction of the Collider vacuum performance for a given choice of bore tube in advance of actual operation. It is worthwhile to point out that we do not yet have the capability to do this with certainty for any choice of bore tube although we expect to have this capability in the near future. The difficulties can all be traced to the cryosorption that occurs on a 4.2°K surface and do not occur at room temperature, where all previous photodesorption experiments have been carried out with the exception of ref.[3] and the recent work in ref.[4] In this section we will discuss two topics: simulation of the synchrotron radiation conditions in a 4.2°K beam tube and measurement of the density of gas molecules inside the 4.2°K tube.

The photon radiation spectrum for the Collider can readily be obtained at existing electron synchrotron light sources or storage rings—e.g., the UV ring at the BNL NSLS and VEPP2M at BINP, Russia—so these facilities are natural to consider for simulation experiments. At the present time experiments related to the Collider vacuum are being carried out at both of these facilities. Aside from the spectrum some details differ from the precise conditions in the Collider: angle of incidence, vertical illumination, low energy cutoff and intensity. For example, to get integrated photon fluxes equivalent to one year of Collider operation, it is desirable to operate at approximately ten times the Collider intensity to carry out the experiments in a reasonable time. However these differences of detail are not believed to be serious limitations. The primary goals of the experiments are to duplicate the synchrotron radiation spectrum and obtain data for integrated photon fluxes corresponding to a year or more of Collider operation (~2×10^{23}photons/m).

Since photodesorption of gas is thought to be a two step process—production of a photoelectron followed by electrodesorption of the gas[6]—there is also the possibility of simulating photodesorption with a source of electrons. This approach is being carried out in laboratories at the SSCL and at UTA. The advantage of this approach is that low energy electron sources are easy to obtain and one does not have to use a synchrotron light source. The disadvantage is that the precise correlation between photodesorption in a beam tube and electron desorption isn't yet known and is not trivial to obtain. However even if it turns out to be necessary to do photodesorption experiments the electron experiments are useful for screening different materials.

So far the density of molecules inside 4.2°K beam tube experiments has been inferred from measurements outside the beam tube with quadrupole residual gas analyzers (RCA's) and ionization gages (IG's). In one experiment the RCA's were configured as molecular beam type detectors and calibrated with gas sources inside the tube.[4] This method has the advantage that the molecules that are detected have not collided with the wall between the beam tube and the RCA ionizer and the density measurement is independent of the molecular velocity distribution. The

disadvantages are that the sensitivity is low—the density in the RCA ionizer is about .01 times the density in the tube—and the RCA ionizer has to be mounted very close to the 4.2°K beam tube, which causes difficulty with cryostat design and heat leaks to 4.2°K. In the more recent experiments the RCA is at room temperature and configured as an equilibrium type detector—the molecules make many wall collisions between the 4.2°K beam tube and the RCA ionizer.[5] For each gas the RCA's are calibrated in the normal fashion against an absolute pressure gage. The advantages of this approach are that the sensitivity is high—the density in the RCA ionizer is 0.12 times the density in the 4.2°K tube—and the RCA's do not need to be mounted close to the beam tube. The disadvantage is that the density in the ionizer is not independent of the molecular velocity distribution inside the 4.2°K beam tube.

Two methods are being developed for direct measurement of gas density inside a 4.2°K beam tube. Both use physical processes that depend linearly on the gas density in the tube. The first is being done at BINP, Russia and is based on detection of the neutralization fraction of a 20keV, 10mA H^- beam directed along the beam tube axis. The second involves measurement of the annihilation rate of a low intensity positron beam directed along the tube axis and is being done at BNL. These methods should reduce the uncertainty involved with inferring density inside the 4.2°K beam tube from measurements outside.

(b) Modeling of the 4.2K beam tube vacuum.

The 4.2°K bore tube of the Collider is subdivided into 90m long sections between external pumping stations. The pumping speed of the cryosorbing 4.2°K beam tube is very large compared to the axial conductance of the beam tube to the external pumping stations. Therefore it is a good approximation to regard the beam tube as infinitely long and axially uniform and to neglect the effects of the pumping stations which are only useful for removing gas during pump down from atmosphere and during beam tube warm ups. The beam tubes used for photodesorption experiments are much shorter—one to four meters—and for these it is not possible to ignore the ends. Furthermore it does not seem practical to do photodesorption experiments with tubes long enough that end effects are negligible—the estimated length of such tubes is ~15m. For this reason it is necessary to develop a model of the 4.2°K beam tube, use the simulation experiments to determine the important parameters and then use the model to predict what will happen in the Collider.

A phenomenological model based on quantities measured in simulation experiments has been developed to predict Collider vacuum performance.[7] The model contains gas source terms from photodesorption of chemisorbed and cryosorbed gases and from thermal desorption. Gas pumping occurs by axial diffusion and cryosorption on the beam tube wall. Distributed pumping in liner configurations and by specially added cryosorber material such as charcoal and porous metals are also treated. Given the desorption coefficients, wall sticking coefficients and mean molecular speeds, the model predicts the build up of gas density in the 4.2°K Collider beam tube and the interval between beam tube warm ups.

In order to completely determine the parameters of the model three auxiliary measurements are needed in addition to the beam tube gas density described in paragraph (a) above. These measurements are: (1) mean molecular speeds inside the 4.2°K beam tube, (2) 4.2°K beam tube sticking coefficients and (3) the H_2 isotherm. Mean molecular speed can be gotten from the time decay of the gas density when the photon beam is gated off. The technique requires a detector with fast time response such as the molecular beam RCA in ref.[4] or the scintillator/neutral beam detector planned for the BINP H^- beam. Molecular sticking coefficients are being measured at BNL using a variable temperature gas nozzle doser and photoemission spectroscopy to measure cryosorbed surface density. The H°2 isotherm is the equilibrium vapor phase density as a function of the surface density cryosorbed on the beam tube with the temperature held constant. It arises as an equilibrium between thermal evaporation and cryosorption or sticking of molecules to the beam tube. The H_2 isotherm has been measured in the cryostat at BINP for an electrodeposited Cu beam tube by inserting a gas dosing tube with many small holes along its length. The H_2 density was measured as the surface density was steadily increased. When a surface density in the neighborhood of one monolayer was reached the H_2 density reached its constant saturation value, which is characteristic of bulk H_2 and independent of the underlying surface. Since the effective surface area and monolayer density are different for each material, this type of measurement needs to be done for each candidate beam tube tested.

(c) Origin of photodesorbed gases.

Although photodesorption has been studied for a number of years there does not yet exist a fundamental understanding of how this process actually occurs, what

form the gas is in before it is photodesorbed and where the gas is located. The resolution of the Collider vacuum issues does not rely on having this fundamental understanding. However if such an understanding were obtained it could help optimize the solution that is taken. It is known that certain types of pretreatment—baking, ion bombardment or glow discharge cleaning, prolonged vacuum pumping, hard acid etching—can reduce the magnitude of photodesorption coefficients. Metal surfaces that are untreated except for routine detergent and solvent cleaning generally have photodesorption coefficients that are roughly equal. The exception is aluminum which usually has photodesorption coefficients several times higher than other metals. This suggests that surface oxide and hydrocarbon layers and molecules chemisorbed to the surface play an important role. Other possible sources of gas include grain boundaries, pores and diffusion from the bulk metal.

As mentioned previously the photodesorption of gas is usually thought to proceed via the production of a photoelectron which then desorbs a gas molecule. The basis for this is the correlation of the magnitude of photoelectron current collected from a portion of the beam tube surface with the amount of photodesorbed gas.[6] The potential applications of this observation are: simulation of photodesorption by electrons and electron pre-treatment of the beam tube to reduce photodesorption.

(d) Beam tube materials options.

The inside surface of the beam tube facing the proton beam must have a high conductivity layer with product of conductivity times thickness $\sigma t \sim 2 \times 10^{-5}$ Ohms^{-1}. This is necessary for two reasons: (1) to keep parasitic heating by the wall image current induced by the beam to a tolerable level and (2) to provide long enough growth time for the resistive wall instability that it can be stabilized by feedback. This generally restricts the choice of surface layer to a Cu or Al coating inside a stainless steel tube which supports the forces induced by a magnet quench. Al seems to be a disadvantage in terms of photodesorption and a 50μm coating of Cu has been chosen for the baseline. However there are many ways of producing the Cu coating—electrodeposition by several methods, chemical vapor deposition, plasma deposition, coextrusion and explosive bonding. Various arguments have been made that one or the other of these may photodesorb significantly less gas than electrodeposited Cu because of reduced porosity, absence of fibrous/columnar structure and absence of water solutions in the preparation. Since room temperature photodesorption yields from high purity bulk Cu have been measured to be about the same as electrodeposited Cu there is skepticism that any of these alternative Cu preparation procedures will produce a large improvement.[8] Nevertheless data is being accumulated for these possibilities. It has also been suggested that a thin coating of Au may suppress photodesorption since gases have low solubility in Au. Recent experiments with a Au film over electrodeposited Cu did not show a significant improvement.[9] Another idea that has been mentioned is to plate a diffusion barrier of some chemically active metal such as titanium between the bulk stainless steel and the high conductivity layer.

(e) Beam tube pre-treatment options.

The objective of a beam tube pre-treatment option is to reduce the magnitude of photodesorption to a level where only approximately one beam tube warm up per year is needed for vacuum maintenance. There are several processes that are either already known to reduce photodesorption or have been suggested as possible pre-treatments: high temperature vacuum baking, high temperature baking in the presence of a reducing gas such as CO, glow or rf discharge cleaning, electron beam desorption and desorption with ultra-violet radiation. A critical question for any pre-treatment process is whether or not it can be done insitu or only before the bore tube is installed in the magnets. For example, in order not to relieve the mechanical pre-stresses in the collars holding the superconducting coils in place, the bore tube cannot be heated after it is installed in the superconducting magnets. If the pre-treatment cannot be done in-situ then it must either tolerate exposure to atmosphere or assembly techniques must be developed which preserve the pre-treatment during magnet fabrication and installation. If the pre-treatment can in principle be done in-situ then hardware would need to be developed which is compatible with access to the beam tube allowed by the present design of magnets, spool pieces and interconnects. In addition any pre-treatment process should be robust enough to allow recovery from an accidental exposure to atmosphere without requiring expensive replacement of accelerator components or excessive loss of operation time. At the present time no pre-treatment option has matured to the point where it has been demonstrated to reduce photodesorption and has a complete scenario for implementation in the Collider. It is possible that in a one to two year time span one of these pretreatment options could emerge as a real option.

(f) Liner/distributed pump options.

Rather than reducing the magnitude of photodesorption the liner/distributed pump options deal with the vacuum issue by simply pumping the gas. The details of the pump are arranged to be strong enough that the mean gas density meets the 300 hrs beam lifetime requirement and the maximum local density is below the cryogenic limit for power deposited in the cryostats (0.6W/m). The liner is a perforated co-axial tube that fits inside the magnet bore tube. Synchrotron radiation is absorbed on the inside surface of the liner, the desorbed gas is pumped through the perforations in the liner and into the annular space between the liner and bore tube, H_2 is absorbed on cryosorber material (e.g., coconut charcoal) in the annular space and the heavier gases CH_4, CO and CO_2 are pumped on the 4.2°K bore tube surface. The cryosorber capacity is chosen large enough to allow one year of Collider operation before regeneration. Regeneration is accomplished by warming the cryosorber to the range 20-40°K, whereupon H_2 is released from the cryosorber into the vapor phase and pumped at the 90m interval pumping stations.

The role of the liner is to shield the cryosorbed molecules and cryosorber from the view of the primary and scattered synchrotron radiation. If it turns out that the shield is unnecessary, then it could be left out but the cryosorber material on the bore tube retained for pumping H_2. This configuration cannot be ruled out since an actual experiment has not yet been done to test the concept. However several room temperature photodesorption experiments have shown that diffusely scattered synchrotron radiation desorbs gas from regions of the beam tube that are not directly illuminated. In a recent SSCL experiment at BNL the exposure on the side opposite the direct illumination was equivalent to approximately 25% of the directly illuminated side. This suggests that cryosorber placed in the beam tube without a shield to protect it will be illuminated by a significant flux of scattered photons. The prospects of achieving the vacuum goals under this condition are highly uncertain but the concept will be tried within the next year because of the simplification and cost savings obtained if it works.

With the liner approach there is a decision to be made on the temperature of the liner. A natural choice coincides with one of the available refrigeration temperatures of the SSCL cryoplant—4.2°K, 20°K or 80°K. The temperature of the 20°K and 80°K liners are maintained by the flow of GHe through small bore tubes brazed to the outside of the liner and connected to the external refrigeration. Since the 4.2°K liner does not require these heat exchanger loops it is conceptually the simplest and the least costly of the liner solutions.

The advantages, disadvantages ad risks of the six possibilities that have been discussed for resolving the Collider vacuum issues are given in Table 2. These six possibilities are: (1) the baseline electrodeposited Cu bore tube, (2) the baseline plus pretreatment, (3) the baseline plus cryosorber, (4) 4.2°K liner, (5) 20°K liner and (6) 80°K liner. The advantages and disadvantages listed in Table 2 include the impact on upgraded Collider operation at three times the design beam current, abbreviated as 3xI.

Table 2.—ADVANTAGES/DISADVANTAGES/RISKS OF THE VARIOUS APPROACHES

Approach	Advantage	Disadvantage	Risks
1. Baseline	Minimum cost. Maximum clear beam tube aperture.	3xI requires 36kW increase in 4.2°K refrig.	Reduced machine availability due to accumulation of photodesorbed gases.
2. Baseline plus pretreatment procedure.	Maximum clear beam tube aperture.	Requires concept and hardware development. Requires proof of principal. 3xI requires 36kW increase in 4.2° refrig.	Potential loss of machine availability to recover from an up to air accident.
3. Baseline plus cryosorber.	Minimal reduction of beam tube aperture.	Requires development of cryosorber. Requires proof of principal. 3xI requires 36kW increase in 4.2° refrig.	Photodesorption due to direct exposure of cyrosorber to scattered synch. rad. Unknown impact on high freq. impedance. Deterioration of cryosorber adhesion.
4. 4.2°K liner	Conceptually solves the photodesorption problem. Cryosorber hidden from photon flux. Cryosorber can be on the outside surface of the liner. Liner approach with no heat leak risk. Liner approach with no failure of cooling tube risk. Liner approach with minimal reduction of physical aperture. Liner approach with minimum cost	Requires development of cryosorber and liner. Reduced physical aperture. Reduced impedance safety margin May require removable magnet bore tube or reduced bore magnet mole. 3xI requires 36kW increase in 4.2°K refrig. at F sites Increased cost compared to baseline.	Deterioration of cryosorber adhesion.

Table 2.—ADVANTAGES/DISADVANTAGES/RISKS OF THE VARIOUS APPROACHES—Continued

Approach	Advantage	Disadvantage	Risks
5. 20K liner	Conceptually solves the photodesorption problem. Cryosorber on the outside surface of the liner may be possible. Reduced supports heat leak compared to 80°K liner. Negligible radiation heat leak to 4.2°K.	Requires development of cryosorber and liner. Requires development of GHe cooling loop. Reduced physical aperture. Reduced impedance safety margin. 20°K refrig. system needs upgrade to F sites for 1XI and 3xI. Increased cost. Increased technical risk.	Potential thermal shorts to 4.2°K refrig., but reduced compared to 80°K. Failure of 20°K GHe cooling loop.
6. 80°K liner	Conceptually solves the photodesorption problem. 3xI allowed with no impact on refrig. systems.	Requires development of cryosorber and liner. Low emissivity liner required. Required development of GHe cooling loop. Liner approach with the largest supports heat leak. Reduced physical aperture. Reduced impedance safety margin. Cryosorber must be on the inside of the magnet bore tube. Increased cost. Increased technical risk.	Potential thermal shorts to 4.2°K refrig. Failure of 80°K GHe cooling loop.

Question 4. Please describe in as much scientific detail as possible any action or actions SSC management proposes or has proposed in order to resolve the vacuum problem referred to in question (1) above.

Answer. In broad outline there are four possible actions that could be taken to resolve the Collider vacuum issues: (1) install the presently specified electroplated Cu on stainless steel bore tube as is, (2) install the presently specified electroplated Cu on stainless steel bore tube with some type of pretreatment, (3) install a bore tube with an alternate Cu plating technology (including Au films etc.) and (4) install a bore tube with a liner/distributed pump. Technical details of these approaches have been given with the answer to question 3 above. Cost estimates are given with the answer to question 5 below. The first option, since it is the least costly, would be taken if it is demonstrated not to require more than approximately one beam tube warm up per year for vacuum maintenance. The information needed is definitive measurement of the photodesorption coefficients of an electroplated Cu beam tube at 4.2°K for one year of integrated photon flux in the Collider ($2x10^{23}$ photons/m). Experimental programs are in place at BNL and BINP, Russia to obtain this information within the next year. Once the experimental techniques are in place to allow prediction of Collider performance for a given choice of beam tube, we will then be able to evaluate the vacuum effectiveness of the options (2) to (4) as well. It is expected that the information required to make an optimal choice among these options, with consideration of cost and operational availability, will be available within two years.

Question 5. Will the resolution referred to in question (4) increase costs in the design, building, or operation of the SSC? If so, by how much?

The estimated capital and operation costs in excess of baseline for the four possible actions are listed in Table 3 below. The estimates of options (2) to (4) in Table 3 are not for fully developed and cost optimized systems and have significant uncertainties, perhaps of the order ±50%.

Question 6. Will the resolution referred to in question (4) cause a delay in the operation of the SSC?

Answer. The resolution to the Collider vacuum issues is not expected to cause a delay in the operation of the SSC. The vacuum issues are being dealt with in a parallel fashion that does not impact the critical path driven by magnet fabrication and installation. The various options evaluated for resolution are being developed as devices that can be inserted into the as built magnets and spool pieces.

Question 7. Has the vacuum problem referred to in question (1) been brought to the attention of any member of Congress or any staffer of a Member of Congress? If so, which member or staffer, by whom, and when?

Answer. To the best of our knowledge and at the level of detail given in the answer to question 1, the vacuum problem has not previously been brought to the attention of a member of Congress or a staffer of a member of Congress. It is not normal practice to bring technical issues in this level of detail to the attention of a member of Congress.

Table 3.—SUMMARY OF ESTIMATED COSTS OF COLLIDER BORE TUBE OPTIONS

Option	Capital cost(k$) in excess of baseline	Oper. cost(k$)/yr in excess of baseline
1. Elec. Cu (baseline)	[1] 0	0
2. Elec. Cu plus pre-treatment	([2])	0
3. Alternate Cu plating technology	10,000	0
4. Liner/distributed pump		
(a) bore tube plus cryosorber	5,000	
(b) 4.2°K liner	20,000	
(c) 20°K liner	85,000	900
(d) 80°K liner	70,000	155

[1] The baseline capital cost is 30M$ for the stainless steel electroplated Cu beam tube.
[2] The pre-treatment options are not yet mature enough for a cost estimate to be given.

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[9] C. Foerster, private communication.

[Appendix]

PARTICIPANTS IN COLLIDER VACUUM RELATED MEETINGS

A. April 10, 1991 SSCL Collider Vacuum Discussions.

Name and institution

Bastasz, Robert, Sandia, Livermore
Briggs, Richard, SSCL
Carcagno, Ruben, SSCL
Chinowsky, Willi, SSCL
Chou, Weiren, SSCL
Dylla, Fred, OEBAF
French, Jim, SSCL
Haas, Gregory, DOE
Jostlein, Hans, FNAL
Lee, James, Brookhaven College
Limon, Peter, FNAL
Lippel, Phil, UT Arlington
Maschke, Al, SSCL,
McAshan, Mike, SSCL
Meinke, Rainer, SSCL
Mulholland, George, SSCL
Palermo, Steve, SSCL
Rosenberg, Richard, Univ. of Wisc. Synch. Rad. Lab
Sauer, Larry, SSCL
Stiening, Rae, SSCL
Turner, William, LLNL
Watson, William, DOE
Wilson, Kenneth, Sandia, Livermore
Zbasnik, Jon, SSCL

B. May 2-3, 1991 CERN Vacuum Wotkshop.

Name and institution

Bacher, Jean-Paul, CERN
Benvenuti, Chris, CERN
Bintinger, David, LBL
Brvnet, J-C, CERN
Calder, Roger, CERN
Chapman, Cerry, CERN
Chou, Weiren, SSCL
Dalin, Jean-Michael, CERN
Faugeras, Paul, CERN
Cavaggio, Richard, CERN
Comez-Coni, Jesus, CERN
Crobner, Oswald, CRRN
Hilleret, Noel, CRRN
Ishimaru, Hajime
Jostlein, Hans, FNAL
Laurent, Jean-Michael, CERN
Lebrun, Philippe, CERN
Maschke, Al, SSCL
Mathewson, Alastair, CERN
Meinke, Rainer, SSCL
Neil, Steve, CERN
Pearce, Norman, CRRN
Poncet, Alain, CERN
Reinhard, Hans-Peter, CERN
Reardon, Paul, SSCL
Reymermier, Christain, CERN
Szeless, Balazs, CERN
Strubin, Pierre, CERN
Trines, Dieter, DESY
Unterlerchner, CERN
VanRooy, Mattheus, CERN
Wahl, Harmut, CERN
Watson, William, DOE
Zbasnik, Jon, SSCL

C. Nov. 13, 1992 Proton Collider Vacuum Technical Meeting at SSCL.

Name and institution

Robert Bastasz, Sandia, Livermore
Richard Briggs, SSCL
Alex Chao, SSCL
Joe Cipriano, DOE
Wayne Clay, SSCL
Eugene Colton, DOE
Jim Compton, DOE
Don Clark, SSCL
Per Dahl, SSCL
Seshu Desu, Virginia Polytechnic Institute
Robert Diebold, DOE/SSCL
Gerry Dugan, SSCL
Conrad Foerster, BNL, NSLS
Oswald Grobner, CERN
Roberto Kersevan, SSCL
Sergey Kurennoy, SSCL
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Gu Qua Lu, Virginia Polytechnic Institute
Jim Maddocks, SSCL
Don Martin, SSCL
Alfred Maschke, SSCL
Igor Maslennikov, SSCL
Alastair Mathewson, CERN
Mike McAshan, SSCL
Rick Mihelic, SSCL
William Nexsen, SSCL
Jack Peterson, SSCL
Danny Punch, DOE
M. Ganapati Rao, CEBAF
Rex Richardson, SSCL
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E.D. Ruiz, SSCL
Georg Schaffer, SSCL
Roy Schwitters, SSCL
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V. Thiagarajan, SSCL
William Turner, SSCL
Linda Walling, SSCL
Alex Weiss, UT Arlington
John Worden, SSCL
Kun Yu, SSCL
Adnan Yucel, SSCL
Jon Zbasnik, SSCL

D. Nov. 13, 1992 Beam Tube Size and Coating Meeting at SSCL.

Name and institution

Aksel, Bulent, SSCL
Archer, William, SSCL,
Argarwal, Ken, GD
Clark, Don, SSCL
Coombes, Roger, SSCL
Franciscovich, Jim, SSCL
Glasgow, Dave, SSCL
Johnson, Dave, SSCL
Leung, Kent, SSCL
McKeown, Mike, Kurt Lesker Co.
Mihelic, Rick, SSCL
P,S, GD
R,R, GD
Shu, Quan Sheng, SSCL
Simmons, Jon, SSCL
Snitchler, Greg, SSCL
T,L, GD
Tuli, Manny, SSCL
Turner, William, SSCL
Waynert, ?, B&W
Wiggins, Kirk, SSCL
Wright, Steve, Kurt Lesker Co.

E. May 24-25, 1993 Second Proton Collider Vacuum Technical Meeting at SSCL.

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Robert Gluckstern, Univ. of Maryland
Ed Gray, LANL
David Green, SAES
Hajime Ishimaru, National Laboratory for High Energy Physics, Japan
Qing-Tang Jiang, UT Arlington
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Jim Maddocks, SSCL
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Dennis Manos, College of William and Mary
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APPENDIX II

Additional Material Submitted for the Record

STATEMENT OF JEROME I. FRIEDMAN

I have been an experimental particle physicist for 35 years and have taught young people for nearly that long. It is from the perspective of a scientist and an educator that I think it is vital to continue the construction of the Superconducting Super Collider.

While we have made great strides in understanding the structure and interactions of the fundamental constituents of matter in the past 40 years, our current theory is incomplete, leaving many questions unanswered. Progress in the illumination of these questions is at a standstill because the information that can be enacted from experiments at currently available energies is insufficient to construct a more complete theory of matter. Theorists are awaiting guidance from experiments at higher energies in order to proceed further. The SSC is absolutely necessary to surmount this barrier. We know of no other way to advance our understanding.

Since 1983 the construction of SSC has had the highest priority in the U.S. particle physics program, and the scientific reasons for building it are more compelling than ever. It will provide a pathway to a possible final theory of what the world is made of and how it is put together. Not only will this be important in itself—as one of the crowning achievements of our civilization—but history has shown that advances in basic knowledge have resulted in revolutions in technology that have led to vast improvements in our standard of living.

When Faraday did his crucial experiments in electricity and magnetism in the early 1800's, these phenomena were considered laboratory curiosities. But this work and the later unification of electricity and magnetism by Maxwell led to the development of motors, generators, electric lighting, communication by telephone, radio, and television, radar, and many other devices upon which our society so heavily depends.

At the end of the 1800's, studies of the spectra of atoms and other seemingly esoteric investigations led to the development of Quantum Mechanics in 1925. Quantum mechanics was an essential ingredient in the invention of the transistor in 1947, one of the great technological developments of the 20th century—a development which set the stage for revolutions in communication, computation, and automation. A sizable fraction of our GNP is based in part on the transistor and its offspring, the microchip.

One could point to many other technological achievements that would not have been possible without quantum mechanics, such as nuclear energy, lasers, superconductors and the countless ways these are applied. These all came about because of curiosity and a dedication to understanding the basic laws of nature.

We cannot predict the applications of the basic research from the SSC any more than Faraday could predict in 1830 the great revolution in technology that would result from his work. Even great scientists have had difficulty anticipating such applications. Ernest Rutherford, the discoverer of the atomic nucleus, said in 1933 "anyone who expects a source of power from the transformation of the atom is talking moonshine." It is ironic that the first chain reaction took place only nine years later at the University of Chicago.

While the construction of the SSC is driven by the importance of the science it addresses, it will provide additional benefits to the Nation. One of these benefits will be to advance various technologies and transfer them to industry, because the SSC presents unique technological challenges to the industries that are building its components. The construction of 10,000 superconducting magnets within extremely small tolerances is developing super conducting technology in industry. The cryogenic and high vacuum systems being designed for the SSC are far larger than any previously constructed, and they present new technological challenges. New types of ultra fast electronics and massive parallel computer processing are being

developed to detect, sort out, and record the proton-proton collisions of interest from the 100 million per second expected to occur in each of the large complex particle detectors being designed for the SSC. The computing needs of the SSC will rival or exceed those found in the most demanding projects anywhere in the world. The SSC goal of distributed computing capacity for as many users as possible combined with immense computing power will make great demands on the technology.

The above examples are a few of the many formidable technological challenges of the SSC that are raising current technologies to new levels and will be instrumental in developing new ones. Solutions will require collaborative efforts between the SSC, industry, and the universities.

A number of these solutions will result in technological spin-offs or applications. There are many examples of past applications of the technology and results of particle physics. These have occurred in such diverse areas as medical diagnostics and therapy, the development of electronic devices, and computing. Some examples in the medical area are the following: the use of particle beams to treat cancer and other disorders, positron-emission tomography (PET) used for medical diagnosis, and the use of radio-isotopes for diagnosis and therapy. The development of super conducting technology for accelerator magnets has led to improvements in Magnetic Resonance Imaging (MRI). Synchrotron radiation sources, which are electron synchrotrons designed to produce intense beams of photons, are being employed in medicine, biology, and materials science. An important technical application is the use of these sources to manufacture microchips with greatly increased circuit densities. Another type of accelerator is used to implant ions near the surface of semiconductors, a process which is an essential step in the fabrication of integrated circuits.

The SSC will also have an important impact on education. Over 100 universities and colleges across the Nation are already participating in planning the scientific program of the SSC. It will be the training ground for thousands of our most talented students, who will provide future scientific leadership in the nation's universities, high tech industries, and government laboratories. It will create a pool of engineers and technicians at the leading edge of technology that will become a resource for America's industry. It will be the world center of high energy physics and will bring in the best minds and ideas from other countries.

The boldness of the SSC in concept captures the imagination of the public. Its objective to probe the innermost structure of matter and recreate in the laboratory conditions similar to those an infinitesimal fraction of a second after the birth of the universe addresses a longing that we all have to understand what we are made of and how we got here. A project such as the SSC whets the curiosity of young people and can attract them to careers in science and engineering. More of our young people must be attracted to these disciplines to assure our nation's status as a leader in science and technology—leadership which is essential for our economic well-being in an increasingly competitive world.

There has been enormous technical and scientific progress at the SSC. The performance of the super conducting dipole magnets exceeds design specifications. Last August—six weeks ahead of schedule—the SSC Laboratory successfully tested the basic subsystem of super conducting magnets that will be the principal components of the super collider. One thousand American high energy physicists—approximately half the total—and nearly as many foreign scientists have already committed themselves to the SSC experimental program and are participating in scientific planning and the design and engineering of the SSC's large detectors.

In a sense the SSC is no longer just a project. It is a world class scientific laboratory coming into existence. Many thousands of men and women across the Nation are working to make it a reality. It is vital that this work continue. The SSC is an intellectual adventure that will enhance the quality and creative climate of our society. The SSC will in a large way contribute to the most important asset we have as a nation, the sum total of the ideas, knowledge, and skills of our people. It will provide a journey of exploration into new realms of knowledge and be our legacy to future generations.

I would like to end with some personal comments. I have come here to plead for the continuation of the SSC not for myself—because I will be in retirement when this accelerator is projected to be completed. I come here to speak for the young physicists and students who want to make contributions to this fundamental field of knowledge. My students exhorted me to do a good job persuading you, because without the SSC they do not see a long term scientific future for themselves in this country. These brilliant young people, and many more like them, would be forced to leave their field or do their research in other countries if opportunities materialize there. This would be damaging not only to these young people but to the science and technology of our nation. If SSC construction is stopped, not only

will we lose the knowledge gained by building and using this unique research facility, but we will be telling our young people that science is no longer a high priority in our nation.

It will be sad if historians of the future note that in 1993, the United States decided not to continue mankind's quest to extract nature's deepest secrets about what the world is made of and how it works—that the cost of the SSC, less than 1% of the federal research and development budget, was too great for the greatest nation on earth to continue this historic quest. This would be a tragic loss. Please do not let it happen.

STANFORD UNIVERSITY,
STANFORD LINEAR ACCELERATOR CENTER,
July 26, 1993.

Senator J. BENNETT JOHNSTON,
U.S. Senate, Committee on Energy and Natural Resources, Washington, DC.

DEAR SENATOR JOHNSTON: Thank you for your invitation, dated July 20, 1993, to testify to the Committee on Energy and Natural Resources and the Subcommittee on Energy and Water Development of the Committee on Appropriations during the hearing originally scheduled for Tuesday, July 27, 1993. It is my understanding that the hearing has now been shifted to August 4, 1993, and been shortened from its original scope.

Accordingly my testimony will not be given during the hearing. Instead I am submitting for the record the attached statement to take the place of the testimony I was prepared to give. With many thanks for the opportunity to participate in these important proceedings.

With best personal regards,

WOLFGANG K.H. PANOFSKY,
Director Emeritus.

[Attachment.]

STATEMENT OF WOLFGANG K.H. PANOFSKY

Mr. Chairman and members of the committee, I appreciate the opportunity to submit this statement to you on the status and expectations of the Superconducting Super Collider program currently executed by Universities Research Association under contract with the Department of Energy. I am the retired Director of the Stanford Linear Accelerator Center. I served in that capacity since the beginning of the construction of that laboratory, under contract with Stanford University, on schedule, on budget and exceeding performance specifications. Its research work has been highly prominent world-wide and led to the award of four Nobel prizes. I am currently Chairman of the Board of Overseers for the Superconducting Super Collider but I am testifying as an individual. This Board is appointed by the Board of Trustees of the Universities Research Association and is charged with broad oversight on behalf of the corporation over the performance of the Superconducting Super Collider Laboratory. Its oversight includes the search for and approval of the senior scientists at the laboratory and the top managers of the Collider project. The membership of the Board is attached to my statement. It includes eminent individuals from industry and the academic community and senior scientists from foreign laboratories. About half of the members of the Board have first hand experience with the technology involved in high energy colliders. Also about half have experience in executing large construction projects.

During the hearing of June 30, 1993, the Secretary of Energy expressed doubt whether the past experience of URA was adequate to run a project as large as the SSC. Similar concerns have been expressed by the then Secretary of Energy during the previous Administration.

URA has been the contractor for designing and building the largest basic science facility in the world. This is Fermilab, constructed under contract with DOE (or its predecessor agencies). The initial construction of that laboratory was accomplished below budget, actually with funds returned to the U.S. treasury, and on schedule. The total capital investment in Fermilab, escalated to current dollars, is about two billion dollars. While this is well below the expected cost to construct the SSC it is a very considerable sum, unprecedented for this class of facility. The functions of URA are exercised not as much through pre-existing management and staff but through its unique relationship to the scientific and technical community to attract and retain an unusual amount of talent, functioning with the highest of motivations to execute the type of work which we are discussing today.

The record of construction under contract to DOE (or its predecessor agencies) by non-profit corporations operating under Government-Owned Contractor Operating contracts has been excellent. The ratio of completion costs to initial cost estimates for the construction of all the nation's high energy physics laboratories since World War II has been 1.03. This performance is spectacularly superior to that of the record of reactor complexes and high technology space and military enterprises.

Much has been said about the reason for that success. Dominant among the reasons is the fact that construction under the Management ad Operations contract system has been carried out while integrating the builders and users of the facilities to be constructed. Thus the future users of the facility could remain in intimate communication with the builders and the construction of instruments for use of the facility could proceed in parallel with the construction of the primary facility.

It is this pattern which is intended to be followed at the SSC. It would be disastrous if DOE attempted to contract separately for construction of the "facility" and the "science." It would be equally disastrous if the "conventional construction" were contractually separated from the construction of the high technology components considering the innumerable number of technical interfaces between these two undertakings.

There is nothing in the history of past M&O managed construction projects which indicates that non-profit M&O academic contractors have an inferior record in managing the conventional construction phases of the overall project. On the contrary, the records of managing conventional construction on-time and within budget have been superior to those managed directly by the government. I note that the conventional construction phase of the SSC is on schedule and clearly proceeding below budget although I admit that credit for this fortunate event is in part due to the depressed condition of the U.S. construction industry.

Today I am to testify on management issues related to the Superconducting Super Collider. The objective of management should be to accomplish the mission of the laboratory at the lowest feasible cost, optimum performance, and fullest accountability to the American taxpayer. Unfortunately questions have been raised concerning the management of the laboratory to the exclusion of consideration of technical performance and scientific merit. The Secretary of Energy has testified on June 30, 1993, that "the science and the technology is not in question." I find it difficult to deal with management as an abstract subject dealing only with process while disregarding the mission which is to be accomplished and ignoring the efficiency with which it is to be attained.

Technical progress at the Superconducting Super Collider Laboratory has been most impressive, in particular in view of the difficult circumstances under which much of the work at the Laboratory is proceeding. Construction has progressed nearly precisely in accordance with he master schedule. Tunnel excavation is proceeding at a record pace. Detailed engineering and design of the injection chain is on schedule. The string test has established that there are no fundamental obstacles to magnet construction. All of the relevant technical design problems are being addressed and most have been fully solved.

I would have much preferred if the nation at this time could focus on what in my view remains the primary issue regarding the Superconducting Super Collider: the question of priorities. Can and should the nation afford to build the leading instrument in the world for research in elementary particle physics, that is research on the physical nature of our universe and our existence, in view of urgent competing social needs? My personal view is that the nation can and should proceed with the Superconducting Super Collider after 20% of completion of construction.

The management issues I can address here only briefly are those raised by the Secretary of Energy, the prematurely released report of the Inspector General of DOE, statements by Congressman Dingell and GAO reports. These statements raise policy questions which go much beyond whether the SSC should or should not go forward. They challenge the National Laboratory concept which has been one of the success stories of American science starting with the end of World War II. The Secretary of Energy in her testimony, dated March 30, 1993, before the Committee on Science, Space ad Technology of the House has praised this concept when she stated: "the Government-Owned, Contractor-Operator (GOCO) laboratories have one common attribute, they were created based on the concept of partnership—the government enlisted the help of the private sector to assist it in furthering national goals." and "This relationship has been a resounding success in attracting the best scientists and engineers in the country to work on important national programs. The accomplishments of the DOE laboratories are recognized throughout the world. Further, this approach has been applied successfully to problems of national importance and is clearly consonant with current and emerging national priorities." and then she continued "I plan to establish a new partnership with the laboratories

without any loss of accountability to the taxpayer and Congress. I am setting as one of my top priorities, strengthening the government-private sector partnership, . . ."

Unfortunately the conduct of the various investigations which we are addressing today has contradicted those goals expressed by the Secretary and has exhibited a deplorable lack of "due process." The report of the Inspector General of DOE was released while in draft preliminary form; it had been released before receiving comments for factual accuracy by those doing the work. The investigation was carried out not primarily by government auditors but by subcontractors not familiar with the Government-Owned Contractor-Operated contractual relationship and unfamiliar with the technical nature of the Superconducting Super Collider mission.

The URA and the SSC management are fully willing to make any changes in the interest of improved management practices, operating efficiency and accountability, and to cooperate with DOE to accomplish this goal. However one should be aware of the fact that most of the criticisms which had been directed at the laboratory by the scientific community, by its overseeing boards, by the laboratories review and advisory committees have been in the direction of deploring excessive bureaucratization, the slowness of the technical and program decision processes, and the impediments which stifle creative initiatives from within the laboratory for improved performance. Foreign visitors are appalled of the level of intrusiveness of oversight in the substantive work of the laboratory. U.S. competitiveness is clearly at risk.

Throughout my entire experience in participating in the work of scientific laboratories and high technology construction projects I have never seen an activity with a greater level and multiplicity of external oversight as the Superconducting Super Collider Laboratory. The DOE maintains over 100 continuous monitors at the laboratory, the GAO, Inspector General of DOE, Congressional committee staff, ad hoc review and appraisals add to these numbers so that at any given moment roughly 200 persons are auditing and reviewing the work of the laboratory. This has resulted in a very large burden on the laboratory to responsibly meet these inquiries, and has resulted in a large increase in indirect costs. Let me emphasize that URA and its Boards and the laboratory management are aware of its obligation to fully cooperate with these oversight functions and is doing all they can to improve performance in this respect. The proposal to have government oversight concentrated onto a single focus in the laboratory would be a substantial improvement. Any further changes in management should simplify the reporting chain and should decrease, not increase, administrative overhead costs.

Creation of the Superconducting Super Collider Laboratory is not a "project" in the ordinary sense. The mission of DOE and URA is to construct the world's leading laboratory in elementary particle physics in which the SSC complex is to be the principal tool. Both objectives, the actual construction of the collider complex on schedule, within cost estimates, and within proposed performance must be paralleled by the establishment of a laboratory in which creative research can flourish; both goals must be met by management. Unfortunately the second of these dual objectives tends to be ignored in these discussions concerning the project; yet it is the quality and quantity of research in this leading facility that will ultimately determine the value the U.S. taxpayer has received.

Let me illustrate this point by addressing the primary items in the Inspector General's report addressing the laboratory's management. The largest monetary item in the IG report criticizes the practices which the SSC laboratory has employed in securing collaboration from the other U.S. national laboratories. The report criticizes the SSC laboratory for not engaging in competitive bidding to provide the services now undertaken by the other laboratories but instead signing Memorandum Purchase Orders (MPO) to obtain such work. The IG report also criticized that MPO's would not spell out in sufficient detail exactly what services were to be provided at what costs. Let me explain the actual situation.

The very existence of the SSC was made possible through the work of Fermilab, the Brookhaven National Laboratory and Lawrence Berkeley Laboratory on superconducting magnet technology. It was the success of Fermilab's collider and research with that facility which led to the proposal to extend this technology to the unprecedented energy to be attained by the SSC. This extension implies transfer of this technology from the other DOE laboratories to the SSC. Considering the size and complexity of the SSC magnet program it is essential to involve American industry in the process. Thus the SSC made arrangements with the other laboratories for transfer of superconducting magnet technology both to the SSC staff and also to two industrial contractors—General Dynamics and Westinghouse. The initial phases of this program, which is the one under criticism by the IG, was a resounding success measured by any of the values which are the stated objectives of the government. The technology was successfully transferred to the two

companies in question. The staff of Westinghouse and General Dynamics successfully produced ahead of schedule, exceeding specification and within the budget line provided by the laboratory, a series of magnets which constituted the "string test" which demonstrated beyond a doubt that the fundamental technical questions concerning the magnets had been solved. The work and the process were approved by DOE and met the provisions of Federal and DOE acquisition regulations.

Thus all technical, financial ad performance goals were met and the same time conversion of two defense contractors to a new civilian technology—superconducting magnets—was carried out. Then what are the complaints? The IG attacked the administrative process used in achieving this success story. Yet competitive bidding would have made no sense whatever since it is well known that the source of the technology was resident in the DOE laboratories. A more formal subcontract process could have been used in place of the Memorandum Purchase Orders, but this is a matter of business judgment, not applicable regulation. If the government desires, URA in the future can and will increase the formality of its inter laboratory collaborative agreements.

A second major IG criticism relates to the use URA makes of the so-called "management allowance" which is provided for in its contract with DOE. URA is carrying out its work without any fee or profit. Its Boards are unpaid and its total Washington payroll covers 7 individuals. The management allowance is 0.2% of total contract cost ($1.2M this fiscal year), a very small sum compared to fees and profits and allowances in federal contract practices with other institutions. Of the 0.2% slightly over one half pays the salary and expenses of URA officers and staff personnel. A smaller amount is allocated to the laboratory director for discretionary expenses. Most of this is used to extend hospitality to the many unpaid members of the various review boards, the program and scientific policy committees, and so forth, whose members generously respond to making their time available without compensation to assist the laboratory. These individuals are reimbursed for their travel and subsistence expenses and part of the latter includes dinners catered at local institutions. Clearly the taxpayer gains by this arrangement compared to the usual practice of paying large consulting fees for such expertise.

Beyond this I find items in the IG report which so clearly bespeak of the auditors lack of understanding of the laboratory's mission. I notice that the IG criticizes that the SSC laboratory, in cooperation with other national laboratories, contributes $10,000 for the conduct of a formal summer school to train young people in the science of accelerators and colliders. There is a serious shortage in the country of accelerator scientists and redressing this deficiency by training young people is clearly to the benefit of the nation's program. The Secretary of Energy explicitly endorsed the educational mission of its laboratories. Again this is an example where performance within DOEs mission is being enhanced at a very low cost. Yet the IG identifies such a function as "apparently unrelated to mission."

Finally I would like to comment on the criticism based on the slow pace of putting in place the laboratory's Project Management Control System, as required by contract. Indeed the laboratory has been very slow in putting the computer system for this purpose into active operation; it is now functional. The system in question is a very complex software package which proved difficult to adapt to carry out all its specified functions. A system of this kind has the following essential functions (1) to accumulate costs in literally thousands of categories where such costs are accrued; (2) to tabulate "the value added" to each of these lines of activities, that is to keep track of how much has been accomplished in each item; (3) to project from this input data the completion date and final costs. Indeed such an integrated system is extremely valuable in enabling management to make trade-off decisions among activities in the interest of the project, and to provide early warning of trouble. Yet it is erroneous either to assert that without the software in place there is no schedule and cost control at all or with the system in place adequate schedule and cost control is assured. No computer software system can do that. Human judgment in feeding information to the system as to fraction of work completed is still required; human judgment is still essential in relating experience during the design and engineering phases of the project to the cost of completion. The assertions of GAO and IG reports that before full validation of the software system, the management and DOE were flying blind on cost and schedule control is simply false. That information has always been available to the project manager and he could and did act on that information. I note that currently the system is functional but has not as yet been validated by a DOE team. I also note that there is already a GAO team in place to validate the validation of the operational integrated control system.

The IG report correctly points out that, relative to other laboratories, a much larger fraction of the work of the SSC is carried out through sub-contract rather than inhouse work. In fact about 75% SSC funding is converted by subcontract to work all over the nation and abroad. The SSC is a truly national, and even international, undertaking. Therefore the quality of subcontracting and purchasing management is of paramount importance and URA will do its utmost to improve efficiency and centralize the process. However the IG is incorrect in identifying the past pattern of subcontracting with evidence for overruns. In general subcontracts are awarded by competitive bidding; the low bid is generally considerably below the line item for the work in question which is carried in the laboratory's Work Breakdown Structure (WBS) cost tables. As work on the subcontract proceeds there are instances in which additional work is added to the subcontractor where the subcontractor attempts to make a case for funds above the amount he bid. If the circumstances warrant, the laboratory will indeed permit increases over the bid amount but generally well below the amount budgeted in its internal cost schedules. Such managed cost growth is a matter of cost control, not a symptom of uncontrolled growth as the IG claims; the IG tends to identify any cost increases above the bid amount as evidence of lack of control, which it decidedly is not. It is misunderstanding of this kind which could have been avoided if the IG had permitted review by the laboratory of its allegations.

Let me conclude by stating that I do hope that the partnership between the national laboratories, including the SSCL and DOE, cam be strengthened and maintained as advocated by the Secretary in her earlier testimony. Under that concept the primary technical and managerial talent within the DOE complex resides with the Management and Operation contractors. Historically the role of DOE and its predecessor agencies personnel has largely been that of overseers, planners and regulators, not of line managers. As a consequence of that history the substantive experience of the 100 members of the DOE team at the SSCL is generally relatively low; none of them have any experience with the technical substance underlying the work of the SSCL. Thus while URA is willing and anxious to make any changes in the interest of improved management operating practices, efficiency, and accountability, we take exception to proposals which would dilute the substantive line responsibility, authority and accountability of the M&O contractor, i.e. URA in this case.

Let me close by expressing the hope and even the expectation that the management issues discussed here will be settled, as they should be, by constructive discussions and negotiations between officers of URA and DOE. This should clear the path for what I hope will be approval by the Congress of continued support for the SSC based on its value to the nation.

URA-SSC Board of Overseers

	Collider/ Accelerator Expert	Academic User	Academic Adm.	U.S. National Labs	Industry	Foreign	Large Project Mgmt.
Kernan		x					
Reeder		x					
Gleeson			x				
Neal		(x)	x				
Gluckstern	x		x				
Hollebeek		x					
Sciulli		x					
Billinge	x					x	x
Blume				x			
Evans					x		x
Hackerman					x		x
McDaniel	x		x				x
Narath				x			
Nishikawa	x					x	x
Panofsky	x			x (ret)			x
Walt					x		
Wheelon					x		x
Wilk	x					x	x
18	6	4	4	3	4	3	8

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